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Comparison of two electrofishing gears (backpack and parallel wires) and abundances of fishes of the upper Greenbrier River drainage

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ABSTRACT

Comparison of two electrofishing gears (backpack and parallel wires) and abundances of fishes of the upper Greenbrier River drainage

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The type of electrofishing gear influences capture efficiencies and abundance estimates of stream fishes. Few studies have examined the Holton and Sullivan (1954) parallel wires method of electrofishing. For this study, I modeled removal data with seven sampling occasions of three common species, western blacknose dace (*Rhinichthys obtusus*), fantail darter (*Etheostoma flabellare*), and mottled sculpin (*Cottus bairdi*) from 10 paired sites in the upper Greenbrier River drainage, West Virginia, and estimated capture efficiencies of two electrofishing gear types (the Holton and Sullivan parallel wires method with alternating current and backpack units with pulsed-direct current). Ten candidate models represented alternative hypotheses of how capture efficiency differs among sites, among stream segments, among gear types, and by site covariates of stream width, water current velocity, water depth, and rock size. Additionally, depending on sample size, I modeled capture probabilities based on four sampling occassions for estimates of abundance or reported total numbers of fish species separated by site and gear type. For each sampling occasion and data for western blacknose dace and fantail darter, capture efficiencies of parallel wires exceeded that of the backpack electrofisher at all sites, and were obtained from the best approximating models of either "gear" or "gear + stream width" effects. For mottled sculpin, capture efficiencies of parallel wires was less than that of the backpack electrofisher at all sites, and were taken from the best approximating models with "gear" or "gear + rock size" effects. First pass estimates of capture probabilities of western blacknose dace and fantail darter were consistently higher for the parallel wires sampling. For mottled sculpin, first pass estimates of capture probabilities were consistently highest from backpack sampling. The parallel wires electrofisher with AC electrical current, through use of electrodes that span the width of the stream, effectively samples pelagic, near-benthic, and some benthic species, but is less effective than DC-pulsed backpack gears at sampling species that use under-rock habitats as refuge. Modification of parallel wires to include DC or pulsed–DC current should improve capture efficiencies of benthic fishes in cobble/boulder streams.

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CHAPTER 1: **Literature Review**

This literature review, in part, focuses on the fish fauna of the New River drainage within the Monongahela National Forest (MNF) and provides literature support for my study of abundance estimates of fish populations within the upper Greenbrier River drainage. I was given two options of fish sampling methods within the upper Greenbrier River system (backpack and parallel wires electrofishers). Several regional biologists suggested parallel wires as a preferred method, but little research was available for this sampling method. Therefore, the second part of this literature review provides background information relative to stream fish sampling with electrofishers, and supports my primary thesis focus on capture efficiency of parallel wires electrofishers.

The fish fauna of the 3,719 km^2 MNF occurs primarily within the headwaters of six major river systems (Monongahela, Potomac, Greenbrier, Elk, Tygart, and Gauley, USDA 2006), and includes seven "sensitive" fish species. Sensitive species are identified by the regional forester based on concerns of population viability. Concerns are based on evidence of current and predicted downward trends in population numbers, density, or habitat capability which could reduce the distributions of these species (Lawrence Livermore National Laboratory 2005). Seven species have "sensitive" status within MNF; New River shiner (*Notropis scabriceps)*, Kanawha minnow (*Phenacobius teretulus)*, candy darter (*Etheostoma osburni)*, redside dace (*Clinostomus elongatus*), pearl dace (*Margariscus margarita*), Cheat minnow (*Pararhinichthys bowersi*) and Appalachia darter (*Percina gymnocephala*). The Greenbrier and Gauley rivers occur in the southern MNF, and have populations of four "sensitive" New River endemics (New River shiner, Kanawha minnow, candy darter, and Appalachia darter, USDA 2006) with historic and recent collections in the Greenbrier and Gauley River basins (Addair 1944, Hocutt et al. 1978, Chipps et al. 1993, Sporre 1996, Cincotta et al. 1999, Messinger and Chambers 2001).

The fish fauna of the New River basin is partly a product of both drainage evolution and recent fish introductions (Wellman 2004). Jenkins and Burkhead (1994) listed 8 of 46 native fish species as endemic to the New River basin. The proportion of endemic species to native species in the New River, as well as the number of non-native fishes are among the highest within drainages of the eastern United States (Cincotta et al. 1999). The New River basin was the headwaters of the historic Teays River system, which was probably a major route of fish dispersal from the east-central United States to the ancestral Mississippi (Steeg 1946, Hocutt et al. 1978, Jenkins and Burkhead 1994). Glaciations and deglaciations altered the lower Teays drainage, and headwater streams possibly served as refuge areas (Hocutt et al. 1978). Fish dispersal toward New River headwaters was likely limited by Kanawha Falls, a 7.3 m waterfall dividing the upper Kanawha (New) river system from the lower Kanawha. Kanawha Falls, along with three other upstream cataracts (Wylie Falls, Bull Falls, and Sandstone Falls), may have hindered upstream fish dispersal within the New River (Cincotta et al. 1999, Messinger and Chambers 2001), and is often used to explain the low overall fish diversity and high endemic fish diversity of the New River drainage (Hocutt and Wiley 1986, Hocutt et al. 1978, 1979).

The persistence of sensitive endemics depends on a number of physical, biological and chemical factors. Poor management practices on private and public lands concern managers of the MNF, and include increased sedimentation, increased stream temperatures, decrease habitat conditions and channel stability, and fragmentation of habitat (USDA 2006). Additionally, biological threats of introduced species within the New River system are not well understood (Messinger and Chambers 2001). Hybridization has occurred between congeneric pairs of native and non-native species, such as the Appalachia darter and Roanoke darter (*Percina roanoka*, Hocutt and Hambrick 1973) and variegate darter (*Etheostoma variatum*) and candy darter (Switzer et al. 2007). However, in addition to a need for studies of native/non-native species interactions, managers of the MNF need current data on the distribution and abundances of “sensitive” fishes.

Electricity has been used widely over nearly 50 years in population estimate studies and is generally considered the most efficient method available of live capture of fishes (Funk 1958, Wiley and Tsai 1983, Angermeier et al. 1991). The use of electricity as a fisheries tool was pioneered by Burr (1931) as a means of controlling fish populations. Haskell (1940) created an electrofishing apparatus that worked in streams under 20 feet in width and 3 feet in depth. After the publications of Haskell (1940) and Haskell and Zilliox (1941) the use of electro-shocking as a means to study stream fish populations spread rapidly (Schuck 1945, Funk 1949). Several forms of AC- electric “seines” developed. Funk (1949) designed a seine for wider sites by equipping the unit with a series of floating electrodes. Modifications were made by Larimore (1961) to include fifteen inch drop electrodes from the surface cable. In West Virginia, methods were modified to create a parallel wires unit. These wires were of opposite polarity and extended across the entire stream. This method created a more uniform current; however, it was more difficult to maneuver around bottom structures than single drop line models (Holton and Sullivan 1954). Commercialized DC backpack units have gained widespread popularity in recent years. These units are light, safe, portable, and can be used with smaller crews in comparison to many of the AC gears (Oronato et al. 1998, Young and Schmetterling 2004, Bertrand et al. 2006).

Estimation of population size of stream fishes often involves electrofishing sampling methods within mark-recapture or removal study designs (Seber and LeCren 1967, Wiley and Tsai 1983). Though mark-recapture studies are theoretically superior, removal studies are more suited for estimating fish populations in small rivers where fish are small, habitats diverse, and the fish population is heterogeneous (Johnson 1965, Seber and LeCren 1967, Wiley and Tsai 1981, Peterson and Cederholm 1984). Removal studies use successive catch data from a closed population to estimate capture probabilities and population size. Researchers have examined bias in removal studies with the following three basic approaches (Peterson 2004); stocking known numbers of fish into a site (Rodgers et al. 1992), using dual gear procedure (Bayley et al. 1989, Bayley and Austen 2002), or collecting, marking, and returning fish to a site (Runstrom et al. 2001).

Estimates of abundance and capture probabilities are biased by biological, environmental, and technical factors when obtained from multiple-pass electrofishing removal studies (Zippin 1956, Otis 1978, Temple et al. 1998). Biased estimates of abundance and capture probability are influenced by biological factors of fish size and shape, and species behaviors (Anderson 1995, Onorato et al.1998), physical and chemical environmental factors (Riley and Fausch 1992, Hill and Willis 1994, Kolz 2006) and technical factors such as the experience of the sampling crew (Hardin and Connor 1992), the number of removal passes (Peterson 2004, Meador et al. 2003, Meador 2005), and the statistical estimator (White et al. 1982, Riley and Fausch 1992). Additionally, biased estimates of abundance and capture probability are also influenced by gear type (Vadas and Orth 1993, Weaver et al. 1993, Onorato et al. 1998).

Valid estimates from removal studies require three conditions. First, a population must be closed (i.e., no births, deaths, immigration or emigration). Second, sampling effort is constant for each capture occasion. Finally, the probability of capture remains the same for each capture occasion (Otis et al. 1978, Riley and Fausch 1992). The first two assumptions are met by sound sampling practices. In order to ensure a closed population, sampling takes place over a short time period (Krebs 1999) and block nets are often used for stream sampling. Time on subsequent passes may decline as fewer fish are encountered, but this reflects a reduction in handling time and not a reduction in sampling effort (Riley and Fausch 1992). Constant capture probability is the most difficult assumption to fulfill. Following the first sampling occasion, fishes may become frightened and seek out cover during subsequent passes. Therefore, fishes may become less catchable (Riley and Fausch 1992). To lessen this reduced catchability, electrofishing methods that capture more individuals on the first pass are most desirable (Peterson 2004).

Multiple pass electrofishing is used as an attempt to reduce the influence of sampling biases (Zippin 1956, Otis 1978). Although single-pass (one sampling occasion) electrofishing reduces time and labor costs relative to multi-pass sampling (Meador et al. 2003, Bertrand et al. 2006), some researchers have emphasized the need for a least three sampling occasions for modeling and estimation of capture probabilities and for increasing the precision of abundance estimates (White et al. 1982). Removal studies fail if the population size is not reduced by each sampling occasion (White et al. 1982, Pollock 1991, Heimbuch et al. 1997), and the probability of this type of failure increases with an increase in the number of sampling occasions.

The end goal of an abundance study is to have a reliable estimate of the fish population (Bayley and Herendeen 2000). Reliability is influenced by the ability to capture fishes, or the capture efficiency of a method. Capture efficiency studies have been popular (Pratt 1952, Wiley and Tsai 1983, Bayley and Austen 1988, Bayley et al. 1989, Rodgers et al. 1992, Onorato et al. 1998, Walsh et al. 2002). There have been studies comparing electroshocking to various methods such as seines (Wiley and Tsai 1983, Bayley et al. 1989, Rodgers et al. 1992, Onorato et al. 1998), rotenone, explosives (Layher and Maughan 1984) and snorkeling (Rodgers et al. 1992, Roni and Fayram 2000). Studies have compared different types of electrofishing gears (Pratt 1952, Fisher and Brown 1993, Walsh et al. 2002) as well as different techniques with the same equipment (Vadas and Orth 1993, Simonson and Lyons 1995). Studies of this nature can be very helpful selecting the best approach to obtain reliable population estimates.

Previous studies have compared electric seines to pulse-DC backpack electrofishers. Bayley et al. (1989) conducted an electrofishing comparison with a modified Larimore (1961) unit in warm water streams of Illinois where electrofishing trials were followed by rotenone treatment. Gear efficiency with the electric seine was higher for centrarchids, percids, silurids, esocids and catostomids. Bayley et al. (1989) recommended electric seines to estimate common fish taxa in most wadeable stream sampling situations. Angermeier et al. (1991) modified this method further, and conducted a study in several headwater streams in western Virginia. In their study they conducted 10 pass electrofishing to come up with relative capture efficiencies. This estimate differed from many previous studies in that the absolute size of the population was not required. They found their ratio and cumulative proportions yielded similar results of those efficiency studies using chemical treatments to find absolute efficiencies. Results from this study showed the modified electric seine to capture a greater proportion of fishes than previous studies of DC electrofishing gears (Angermeier et al. 1991). Studies have not estimated capture efficiency associated with the parallel wires method of Holton and Sullivan (1954) to that of a DC-backpack unit.

This thesis includes data on current distributions of sensitive fishes within the Greenbrier River drainage of the MNF, and focuses on electrofishing sampling methods with an emphasis on parallel wires methodology. Specifically, the second chapter is a manuscript of an electrofishing comparison study between backpack and parallel wire units at ten paired-sites and compares the capture efficiencies of these methods. Appended are additional results relevant to the Chapter 2 manuscript, as well as a summary (including distribution maps and data tables) of an additional three-pass study designed to collect distribution and abundance data for sensitive fish species in the Greenbrier River basin within the MNF boundaries.

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CHAPTER 2: Capture efficiency of the Holton and Sullivan parallel wires electrofishing gear in first through fourth order streams

Introduction

Removal sampling with an electrofisher is a common method for estimation of fish abundance in wadeable streams (Johnson 1965; Seber and LeCren 1967, Wiley and Tsai 1981, Peterson and Cederholm 1984). Several electrofishing gears are available, and studies have compared different gear types (Pratt 1952, Bayley et al. 1989, Angermeier et al. 1991, Walsh et al 2002), as well as different sampling techniques, such as the number of sampling occasions, with the same equipment (Vadas and Orth 1993, Simonson and Lyons 1995). Although single-pass (one sampling occasion) electrofishing reduces time and labor costs relative to multi-pass sampling (Meador et al. 2003, Bertrand et al. 2006), some researchers have emphasized the need for a least three sampling occasions for modeling and estimation of capture probabilities and for increasing the precision of abundance estimates (White et al. 1982, Pollock 1991). Removal studies fail if the population size is not reduced by each sampling occasion (White et al. 1982), and the probability of this type of failure increases with an increase in the number of sampling occasions.

Estimates of abundance and capture probabilities may be biased by biological, environmental, and technical factors when obtained from multiple-pass electrofishing removal studies (Zippin 1956, Otis 1978, Kolz et al. 1998). Biased estimates of abundance and capture probability are not only influenced by biological factors of fish size and shape, and species behaviors (Sullivan 1956, Anderson 1995, Onorato et al.1998), and physical and chemical environmental factors (Riley and Fausch 1992, Hill and Willis 1994, Kolz 2006), but also technical factors such as the experience of the sampling crew (Hardin and Connor 1992), the number of removal passes (Meador et al. 2003, Peterson 2004), and the statistical estimator (White et al. 1982, Riley and Fausch 1992). Additionally, biased estimates of abundance and capture probability are also influenced by gear type (Vadas and Orth 1993, Weaver et al. 1993, Onorato et al. 1998).

Electrofishing gear comparisons can be based on sampling efficiency (i.e., the percent of the population captured by sampling, Kolz et al. 1998). The actual population size is generally unknown, so a capture efficiency is often estimated by a ratio of the total number or population estimate from one or multiples passes to an estimated population size. Generally, a high capture efficiency on the first electrofishing pass is preferred, particularly for removal studies where numbers of fish during each pass must be higher than those of subsequent passes (White et al. 1982, Pollock 1991, Heimbuch et al. 1997).

An understanding of gear-influenced biases, such as gear avoidance, is important when designing studies for abundance estimation. Backpack DC electrofishers are commonly used to sample wadeable streams (Oronato et al. 1998, Meador et al. 2003, Bertrand et al. 2006), but other gears are also used, such as Backpack AC units, pre-positioned area shockers (Fisher and Brown 1993, Temple et al. 1998, Walsh et al. 2000), and several modifications of electric seines ranging from electrode arrays with droppers (Bayley et al. 1989, Angermeier et al. 1991, Walsh et al. 2000) to a simple design of two wire electrodes (i.e., parallel wires, Holton and Sullivan 1954). Abundance estimates and associated capture efficiency from backpack DC units are biased, in part, by gear avoidance (Bayley et al. 1989). A parallel-wire electrofisher minimizes this bias because wire electrodes (stretched across the width of the stream) reduce gear avoidance (Holton and Sullivan 1954, Angermeier et al. 1991).

Objectives

Although researchers have compared several types of electrofishing gears (Pratt 1952, Wiley and Tsai 1983, Bayley and Austen 1988, Bayley et al. 1989, Rodgers et al. 1992, Onorato et al. 1998, Walsh et al. 2002), studies have not estimated capture efficiency associated with the parallel wires method of Holton and Sullivan (1954). My objectives were to model and estimate capture efficiencies from a paired-site design of removal studies with parallel wires and backpack electrofishers within the upper Greenbrier River drainage, West Virginia. I provide abundance estimates and total numbers of fish species by sites and gear type.

Methods

Site selection

The study was conducted in the upper Greenbrier River drainage, Monongahela National Forest. During summer and fall 2005, I sampled 10 stream segments (each with paired sites) in the upper Greenbrier River, Pocahontas County, West Virginia: Knapp Creek, Galford Run, West Fork Greenbrier River, Little River of the West Fork Greenbrier River, Little River of the East Fork Greenbrier River, the East Fork Greenbrier River (four sites), and Long Run (Table 1, Figure 1). Elevations of study segments ranged from 831 to 929 m (estimated at locations between paired sites, Table 1). Water conductivities ranged from 31 to 69 μS/cm (Table 1) and primarily reflect the Pocono and Mauch Chunk bedrock geologies of the upper Greenbrier River drainage (Flegel 1999).

The 10 stream segments were selected based on availability of at least two 15 m or greater sections of riffle/run habitat within 100 m of each other. This allowed a paired site comparison of the two electrofishing methods within each sampling reach, and reduced variation in water chemistry for between gear comparisons. A habitat assessment at each site was used to compare paired-sites and to provide habitat-based covariates for analysis. For habitat assessment, each site was divided into 5 equidistant transects. Substrate (a modified Wolman pebble count, Bain and Stevenson 1999), stream depth (m), and water current velocity (m/s) were measured at 20 points along each transect (Figure 1). Also, we measured wetted width at each transect.

Gear description

Holton and Sullivan (1954) described a parallel wire electrofisher powered by a shore-based generator. We modified this design to include a backpack-mounted generator. Specifically, our system was powered by a Honda® 1.8 HP EU1000i generator (120V AC output) and a Staco® variable transformer (model 3PN1020B-XDVM) with 120VAC single phase input, 0-280VAC output, 50/60 Hz, 3.5-1.5A, and digital voltmeter. We used two 2.4 mm zinc coated steel cable electrodes (i.e., "parallel wires") each stretched between two wooden poles (with on/off switches). Cable lengths were adjusted to span the width of the stream, and ranged from 15 to 25 m. Holton and Sullivan (1954) used 12 gauge copper cable as electrodes, but our steel cable electrodes increased maneuverability and decreased cable kink.

Fish sampling methods

Within each stream reach, the downstream site was sampled first with a randomly-selected gear type (parallel wire or backpack electrofisher), and the upper site was sampled either the same or following day using the alternative method. At each site, we installed block nets (6.4 mm mesh) at the upper and lower ends, and conducted seven passes with a single electrofishing gear. For both methods, two individuals operated the gear, and fishes were netted by two or three individuals (the same crew sampled each of the paired-sites). We fished the parallel wires between 150 and 225 volts (depending on the level needed to induce narcosis but not tetany in fishes, Dolan and Miranda 2004) and a portable volt meter documented constant voltage across the entire length of cable. The parallel wires were fished approximately 1m apart, and moved upstream in 1m intervals and two or three people netted fishes. Two Smith-Root® backpack electrofishers (models LR-24 and Model 12B, both with 28 cm electrode rings) were fished with direct current (pulsed–DC) and at 400 volts for most sites (range 300-500 volts). Backpack units were set to a pulse setting of 60Hz with a duty cycle of 5 mSec, and were fished within 5 m of each other and in unison upstream during fish sampling. After each pass, fishes were identified to species, categorized by age (adult or juvenile, Jenkins and Burkhead 1994), and counted. Fishes were retained in tubs after capture and released following data collection of the last sampling occasion or preserved in a 10% formalin solution for laboratory identification.

Data analysis

Capture efficiencies between parallel wire and backpack methods were estimated from removal data of adults of three relatively common species; *Rhinichthys obtusus* (western blacknose daces), *Etheostoma flabellare* (fantail darter), and *Cottus bairdi* (mottled sculpin). Other species and all juveniles were excluded from analysis of capture efficiency because of small sample sizes. Capture efficiency at each site was modeled and estimated separately for the first, cumulative-second, and cumulative-third sampling occasions (hereafter referred to as the 1^{st}, 2^{nd}, and 3^{rd} sampling occasions). The capture efficiency of the first occasion was defined as the proportion of the number collected on the first pass to the total of the seven sampling occasions. The second and third occasion capture efficiencies were estimated as the proportions of the combined 1^{st} and 2^{nd} occasion and the combined 1^{st}, 2^{nd}, and 3^{rd} occasion to the total of the seven sampling occasions, respectively.

I used generalized linear mixed models (PROC GLIMMIX, SAS 2006) with binomial error distribution, log-link function, and randomized block design (block on paired sites) to estimate capture efficiencies for each species and sampling pass. Ten candidate models represented alternative hypotheses of how capture efficiency differs among sites, among stream segments, among gear types, and by site covariates (mean values) of stream width, water current velocity, water depth, and rock size (Table 1). The global model, a site saturated model, parameterized site-specific capture efficiencies. The fit of the global model and an estimate of overdispersion were assessed with the Pearson's chi-square statistic.

I also calculated maximum likelihood estimates of capture probabilities ($\hat{p}$) and abundance estimates ($\hat{N}$) from removal data of parallel wire and backpack sampling methods for the 10 paired-sites (using Program MARK, Cooch and White 2006). Capture probabilities were estimated separately for each species and each site, and second sampling occasion probability ($\hat{c}$) was fixed at 0.0. Candidate models represented alternative hypotheses and were fit to the four-sampling occasion removal data and arranged in order of fit by the second-order adjustment to Akaike's information criterion ($QAIC_c$) (Akaike 1973; Burnham and Anderson 2002). We used the following candidate models: 1) $\hat{p}$ constant among sampling occasions (behavioural model $M_{b,}$); 2) $\hat{p}$ of the first sampling occasion differed from that of the following sampling occasions (M_{bh}, k=2); and 3) $\hat{p}$ differed among first and second sampling occasions but was constant for the third and fourth sampling occasions (M_{bh}, k=3) (White et al. 1982).

For both analyses of capture efficiencies (PROC GLIMMIX) and abundance estimates (Program MARK, $\hat{p}$ and $\hat{N}$), model selection and support for alternative hypotheses followed an information-theoretic approach based on Kullback-Leibler information theory and the second-order adjustment of Akaike's information criterion (Burnham and Anderson 2002). When model selection uncertainty occurred (i.e., two or more models had $\Delta AICc < 4$), then final parameter estimates and unconditional variances were derived from weighted model-averaged estimates and standard errors (Buckland et al. 1997). Also, for both analysis, I calculated mean capture efficiencies (PROC GLIMMIX) and mean capture probabilities (Program MARK) of the first sampling occasion across all ten sites for the three common species for backpack and parallel wires estimates. Standard errors and 95% confidence intervals were calculated using the sum of the variances of the independent sites (Mood et al. 1974).

Results

The paired-site design reduced influences of habitat variation on comparisons of parallel wires and backpack electrofishing gears. Wetted widths were similar between paired sites (within stream segments) and differed among stream segments (Table 2). Additionally, paired-sites were similar in water depth, water current velocity, and rock sizes of stream bottom substrate (Table 1, Appendix 1). The differences of habitat variables were relatively large among sites, and this variation allowed habitat variables to be modeled as covariates in analyses of capture efficiency (range of mean water depth 0.05 – 0.19 m, range of mean current velocity 0.09 –0.36 m/s, and range of mean diameter of rock sizes 80 – 323 mm, Table 1).

Capture efficiency differed among the three study species and between gears, and no overdispersion or lack of fit was detected for global models of the analyses of 1st, 2nd, and 3rd sampling occasions. Capture efficiency of parallel wires exceeded that of the backpack electrofisher for western blacknose dace and fantail darter at all sites, whereas capture efficiency of parallel wires was less than that of the backpack electrofisher for mottled sculpin at all sites (Fig 2). For blacknose dace, capture efficiencies of the 1st, 2nd, and 3rd sampling occasions were each estimated from the additive model of Gear + stream width (AICc weight = 1.000, Table 2) and among-site averages ranged from 0.66-0.85, 0.81-0.94 and 0.90-0.95 for parallel wires and 0.44-0.70, 0.60-0.86, and 0.82-0.90 for backpack electrofisher (Figure 2). For the fantail darter, capture efficiencies were estimated from the Gear model (AICc weight = 0.999, 1st sampling occasion, Table 3) and the additive model of Gear + stream width (AICc weight = 1.000, 2nd and 3rd sampling occasions, Table 3). For fantail darter and the three sampling occasions, capture efficiencies range for the 0.44-0.67, 0.60-0.84, and 0.84-0.89 for parallel wires and 0.40-0.62, 0.54-0.77, and 0.71-0.85 for backpack electrofisher (Figure 2). Capture efficiencies based on data for mottled sculpin were estimated from the Gear model (AICc weight = 0.884, 1st sampling occasion, Table 4), from model-averaging of the Gear and Gear + rock size models for the 2nd sampling occasion (AICc weights = 0.517 and 0.483, respectively, Table 4), and from the Gear model for the 3rd sampling occasion (AICc weights = 1.000, Table 4). For mottled sculpin, among-site capture efficiencies during the 1st, 2nd, and 3rd sampling occasions ranged from 0.37-0.54, 0.56-0.76, and 0.69-0.85 for parallel wires and 0.42-0.58, 0.61-0.80, and 0.72-0.87 for backpack electrofisher (Figure 2).

Cumulative capture efficiencies increase with the number of sampling occasions, but the rate of increase differed among species and between gears. The differences in capture efficiency between gears at paired sites decreased with an increase in the number of sampling occasions. The average differences between paired sites for the 1^{st}, 2^{nd}, and 3^{rd} sampling occasions differed among western blacknose dace (0.18, 0.13 and 0.06) fantail darter (0.04, 0.06 and 0.05), and mottled sculpin (0.05, 0.05 and 0.02). Parallel wires had a higher capture efficiency for western blacknose dace for all sites and all sampling occasions when compared to the backpack electrofisher. Parallel wires also had a higher capture efficiency for fantail darters at all sites and all sampling occasions than the backpack electrofisher. However, these differences in capture efficiency between gears at paired sites were smaller than those of western blacknose dace, and these differences were relatively consistent across the three sampling occasions. Likewise, for mottled sculpin data, the differences in capture efficiency between gears at paired sites were smaller than those of blacknose dace, and these differences were relatively consistent across the three sampling occasions, where the backpack electrofisher had a higher capture efficiency than that of the parallel wires for all sites and all sampling occasions.

Abundance estimates

Twenty-four species were sampled from 10 paired sites (Appendix 2), and $\hat{p}$ and $\hat{N}$ were estimated for three common species (*R. obtusus, E. flabellare, and C. bairdi*) when four-pass sample size exceeded 40 and when the depletion criterion was met (Table 5). For sample sizes of < 40, I reported total counts of individuals because abundances are not estimable with low sample size. First-pass estimates of $\hat{p}$ were highest from the parallel wires sites for 10 of 16 paired-site comparisons. Although parallel wires and backpack electrofishing gears were randomly assigned within paired sites, first pass estimates of $\hat{p}$ for *R. obtusus* and *E. flabellare* at paired sites were consistently higher for the parallel wires sampling (4 of 4, and 4 of 6 four-pass estimates, respectively). For *C. bairdi*, $\hat{p}$ estimates between paired-sites were consistently highest from backpack sampling (4 of 6 four-pass estimates). Estimates of $\hat{p}$ differed from those of capture efficiency because $\hat{p}$ was based on 4 sampling occasions and capture efficiency was base on 7 sampling occasions (Tables 6 and 7). The two estimates would be approximately equal if based on the same number of sampling occasions. However, removal estimation of $\hat{p}$ is often difficult because an increase in sampling occasions increases failure of the depletion criterion. When sample sizes for the three common species were > 40, removal studies failed (numbers did not decrease with sampling occasion) for 10 of 53 four-pass samples. Relative to gear comparisons for 4 sampling occasions, the failure rate was similar for backpack electrofishers (5 of 25 four-pass estimates, 20.0%) and parallel wires (5 of 28 four-pass estimates, 17.9%). Also, four-pass abundance estimates of *R. obtusus*, *E. flabellare*, and *C. bairdi* from both gear types were biased (underestimated) for 33 of 43 estimates relative to total counts from the seven-pass samples.

Discussion

For this study, differences in capture efficiency between parallel wires and backpack electrofishers were influenced by species (phylogenetic constraints and avoidance behavior) and abiotic factors (stream width and rock size). Between-gear differences were partly attributed to the type of electrical current (AC or pulsed–DC). The anodic taxis of pulsed–DC backpack gear (i.e., forced swimming of fish toward the anode, Reynolds 1995) likely explains the higher capture efficiencies for capture data of *C. bairdi* (a benthic species that often occurs under rocks). The AC parallel-wires gear (without anodic taxis) had higher capture efficiencies than that of the backpack gear for *E. flabellare* (a benthic species often found between or under rocks) and *R. obtusus* (a near-benthic or pelagic species). My data supports parallel wires with AC current as an effective gear type for wadeable streams (4-10 m widths) with relatively low conductivities (35-69µS/cm), but the AC gear is less effective when sampling benthic fishes in cobble/boulder streams. Additionally, removal data from parallel wires sampling provided higher $\hat{p}$ estimates than that of the DC-pulsed backpack electrofisher for *R. obtusus* and *E. flabellare*, despite random assignment of the two gears at paired sites.

The removal data for *R. obtusus* and *E. flabellare* supported models of gear effect and stream width. For these two species, I have two separate interpretations of the higher capture efficiencies of parallel wire gear. For *R. obtusus,* the "streaming" and "fountain" behaviors of predator avoidance (Magurran and Pitcher 1987, Helfman et al. 1997) allow individuals to avoid the backpack gear (where avoidance increases with stream width), but the parallel wire electrodes cross the width of the stream and provide a complete barrier at all stream widths. Higher capture efficiencies for cyprinids with AC methods have been reported for electric seines (Larimore 1961, Bayley et al. 1989, Angermeier et al. 1991). *Etheostoma flabellare* does not "stream" as a predator avoidance response, but relies on benthic cover and cryptic pigmentation, essentially staying in place on the stream bottom. As stream width increases, the side-to-side or meandering sampling with the backpack units do not provide complete coverage of the site, and this reduces capture efficiency. In contrast, the parallel wire unit with electrodes stretched across the width of the stream achieves complete coverage of the site during each sampling occasion.

Within gear types, lower capture efficiencies occurred for the benthic fishes (*C. bairdi* and *E. flabellare*). This is supported by other studies, and typically explained by cryptic coloration and sedentary nature (Larimore 1961, Brown and Downhower 1982, Bayley et al. 1989, Angermeier et al. 1991). For among gear types, *C. bairdi* had an opposite interpretation than that of *E. flabellare* (as explained above). For this study, the removal data of *C. bairdi* supported models with a gear effect, but also provided support for an influence of rock size, particularly during the second sampling occasion. For *C. bairdi*, I interpret the use of under-rock microhabitats as a major influence on the overall lower capture efficiencies and differences in capture efficiencies between gear types. Specifically, capture efficiency was lower at sites with larger rocks. The pulsed–DC current educes strong anodic taxis and causes forced swimming toward the anode (Reynolds 1995), and this effect moved individuals of *C. bairdi* away from rocks and into the sight of netters. During sampling with parallel wires, the forced swimming was not educed by the AC electrical current, and a proportion of the total number of individuals remained under rocks and were not netted by the sampling crew.

Parallel wires and backpack electrofishing gears were randomly assigned within paired sites, but both first-pass estimates of $\hat{p}$ and the failure rate to meet the depletion criterion differed between gear types and among species at paired sites. Four-pass estimates of $\hat{p}$ of *R. obtusus* and *E. flabellare* for paired sites were consistently higher at sites of parallel wires sampling, and resulted from higher capture efficiencies of the parallel wire gear. Likewise, the higher capture efficiencies of the *C. bairdi* from backpack gear is reflected in higher four-pass estimates of $\hat{p}$ from that gear type. Although the removal criterion was not met for several four-pass sampling events, the failure rate was not disproportionate among gear types. Abundance estimates from both gear types, however, were biased low relative to total numbers from the 7-pass samples. The bias (underestimates) in removal-estimated abundances has been emphasized by others (Peterson 2004), but does not detract from my findings of differences in sampling gear efficiencies among species and between paired-sites.

In conclusion, characteristics of three common species (use of benthic or pelagic habitat and avoidance behaviors) in combination with stream habitat characteristics (stream width and rock sizes) influenced capture efficiencies of backpack and parallel wires within the upper Greenbrier River drainage. The Holton and Sullivan (1954) parallel wires electrofisher with AC electrical current, through use of electrodes that span the width of the stream, effectively samples pelagic, near-benthic, and some benthic species, but is less effective at sampling species that use under-rock habitats as refuge. For additional research, I suggest further modification of the Holton and Sullivan (1954) parallel wires electrofisher to include DC or pulsed–DC current which should improve capture efficiencies of benthic fishes in cobble/boulder streams.

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Table 1. Location and characterstics of 10 study segments in the upper Greenbrier River watershed, West Virginia. Latitude, longitude and elevation are from the mid-point between compared sections. Strahler's stream orders were calculated on a 1:24,000 USGS Topo map and stream conductivities of sites are given. Averages for habitat variables used as covariates are listed for all sites sampled with backpack (BP) and parallel wires (PW) gears with standard errors (SE).

Stream (site no.)	Latitude	Longitude	Elevation (m)	Stream Order	Conductivity (uS/cm)	Gear	Site length (m)	Velocity (m/s)	Substrate (mm)	Width (m)	Depth (m)
Upper Knapp (1)	38° 16.33'N	79° 51.54'W	831	2	64	BP	25.0	0.09 (0.01)	135 (15)	5.5 (0.3)	0.05 (0.004)
						PW	25.0	0.11 (0.01)	172 (20)	4.2 (0.3)	0.06 (0.004)
Galford Run (2)	38° 22.39'N	79° 48.64'W	851	2	49	BP	20.0	0.11 (0.01)	114 (7)	4.7 (0.04)	0.05 (0.004)
						PW	20.0	0.11 (0.01)	114 (8)	4.3 (0.1)	0.06 (0.004)
Little River of West Fork (3)	38° 37.01'N	79° 48.29'W	897	3	31	BP	20.0	0.24 (0.02)	80 (6)	7.4 (0.5)	0.11 (0.006)
						PW	20.0	0.16 (0.02)	87 (7)	8.7 (0.4)	0.12 (0.007)
West Fork (4)	38° 40.36'N	79° 47.37'W	913	2	68	BP	15.0	0.12 (0.01)	170 (11)	8.9 (0.7)	0.09 (0.004)
						PW	15.0	0.08 (0.01)	191 (18)	9.6 (0.4)	0.08(0.005)
East Fork (5)	38° 32.90'N	79° 45.70'W	862	4	57	BP	20.0	0.17 (0.02)	125 (11)	5.5 (0.2)	0.11 (0.008)
						PW	20.0	0.16 (0.02)	127 (15)	5.8 (0.4)	0.10 (0.007)
Little River of East Fork (6)	38° 32.95'N	79° 43.81'W	893	3	65	BP	20.0	0.30 (0.02)	134 (15)	6.5 (0.2)	0.19 (0.008)
						PW	20.0	0.36 (0.02)	174 (15)	6.2 (0.6)	0.17 (0.008)
East Fork (7)	38° 34.52'N	79° 43.00'W	905	3	37	BP	20.0	0.14 (0.01)	119 (9)	6.5 (0.4)	0.09 (0.007)
						PW	20.0	0.11 (0.01)	124 (8)	6.9 (0.4)	0.10 (0.007)
East Fork (8)	38° 34.59'N	79° 42.87'W	907	3	37	BP	20.0	0.08 (0.01)	216 (24)	9.1 (0.2)	0.11 (0.007)
						PW	20.0	0.08 (0.01)	323 (47)	8.7 (0.3)	0.08 (0.007)
East Fork (9)	38° 34.62'N	79° 42.63'W	910	3	37	BP	20.0	0.14 (0.01)	204 (21)	7.3 (0.4)	0.13 (0.008)
						PW	20.0	0.15 (0.02)	210 (24)	8.0 (0.5)	0.12 (0.009)
Long Run (10)	38° 34.56'N	79° 42.14'W	929	3	69	BP	15.0	0.12 (0.02)	88 (7)	8.1 (0.6)	0.07 (0.005)
						PW	15.0	0.15 (0.02)	122 (13)	7.1 (0.4)	0.07 (0.005)

Table 2. Candidate capture efficiency models and associated model selection statistics for captures of western blacknose dace with parallel wire and backpack electrofishing gears at 10 paired sites (upper Greenbrier River drainage, WV) for the first (A), cumulative-second (B), and cumulative-third (C) sampling occasions including the number of parameters (*K*), the second order adjustment of the Akaike information criterion (AIC_c), difference in AIC_c (Δ_i), and the Akaike weights (w_i) for each model.

A.

Model	–2 log likelihood	K	AIC_c	Δ_i	w_i
Gear + stream width	6133.190	3	6139.207	0.000	1.000
Gear + rock size	6152.090	3	6158.107	18.900	0.000
Gear	6155.080	2	6159.089	19.881	0.000
Stream segment + stream width	6174.520	10	6194.677	55.470	0.000
Stream segment + stream depth	6177.960	10	6198.117	58.910	0.000
Stream segment + current velocity	6178.580	10	6198.737	59.530	0.000
Stream segment + rock size	6206.290	10	6226.447	87.240	0.000
Gear + stream depth	6216.930	3	6222.947	83.740	0.000
Gear + current velocity	6228.540	3	6234.557	95.350	0.000
Site saturated	6257.440	18	6293.931	154.724	0.000

B.

Model	–2 log likelihood	K	AIC_c	Δ_i	w_i
Gear + stream width	6667.590	3	6673.607	0.000	1.000
Stream segment + stream depth	6773.490	10	6793.647	120.040	0.000
Stream segment + stream width	6780.850	10	6801.007	127.400	0.000
Gear + rock size	6788.880	3	6794.897	121.290	0.000
Gear	6790.880	2	6794.889	121.281	0.000
Stream segment + rock size	6795.560	10	6815.717	142.110	0.000
Stream segment + current velocity	6804.080	10	6824.237	150.630	0.000
Gear + stream depth	6838.710	3	6844.727	171.120	0.000
Site saturated	6918.750	18	6955.241	281.634	0.000
Gear + current velocity	6944.720	3	6950.737	277.130	0.000

C.

Model	–2 log likelihood	K	AIC_c	Δ_i	w_i
Gear + stream width	7479.370	3	7485.387	0.000	1.000
Gear	7499.460	2	7503.469	18.081	0.000
Gear + rock size	7507.890	3	7513.907	28.520	0.000
Gear + stream depth	7533.110	3	7539.127	53.740	0.000
Stream segment + stream depth	7552.610	10	7572.767	87.380	0.000
Gear + current velocity	7553.130	3	7559.147	73.760	0.000
Stream segment + rock size	7567.560	10	7587.717	102.330	0.000
Stream segment + stream width	7590.770	10	7610.927	125.540	0.000
Stream segment + current velocity	7618.910	10	7639.067	153.680	0.000
Site saturated	7698.850	18	7735.341	249.954	0.000

Table 3. Candidate capture efficiency models and associated model selection statistics for captures of fantail darter with parallel wire and backpack electrofishing gears at 10 paired sites (upper Greenbrier River drainage, WV) for the first (A), cumulative-second (B), and cumulative-third (C) sampling occasions including the number of parameters (K), the second order adjustment of the Akaike information criterion (AIC_c), difference in AIC_c (Δ_i), and the Akaike weights (w_i) for each model.

A.

Model	–2 log likelihood	K	AIC_c	Δ_i	w_i
Gear	16162.890	2	16166.893	0.000	0.999
Gear + rock size	16175.860	3	16181.866	14.973	0.001
Gear + current velocity	16214.910	3	16220.916	54.023	0.000
Gear + stream width	16247.210	3	16253.216	86.323	0.000
Gear + stream depth	16282.780	3	16288.786	121.893	0.000
Stream segment + stream depth	16364.670	11	16386.739	219.846	0.000
Stream segment + rock size	16365.270	11	16387.339	220.446	0.000
Stream segment + current velocity	16365.670	11	16387.739	220.846	0.000
Stream segment + stream width	16373.010	11	16395.079	228.186	0.000
Site saturated	16463.860	20	16504.080	337.187	0.000

B.

Model	–2 log likelihood	K	AIC_c	Δ_i	w_i
Gear + stream width	16614.620	3	16620.626	0.000	1.000
Gear	16756.820	2	16760.823	140.197	0.000
Gear + rock size	16854.810	3	16860.816	240.190	0.000
Gear + current velocity	16857.120	3	16863.126	242.500	0.000
Gear + stream depth	17011.400	3	17017.406	396.780	0.000
Stream segment + current velocity	17225.260	11	17247.329	626.703	0.000
Stream segment + rock size	17233.210	11	17255.279	634.653	0.000
Stream segment + stream width	17234.410	11	17256.479	635.853	0.000
Stream segment + stream depth	17235.670	11	17257.739	637.113	0.000
Site saturated	17403.980	20	17444.200	823.573	0.000

C.

Model	–2 log likelihood	K	AIC_c	Δ_i	w_i
Gear + stream width	18132.300	3	17908.846	0.000	1.000
Gear	18192.740	2	18136.303	227.457	0.000
Gear + current velocity	18192.740	3	18198.746	289.900	0.000
Gear + rock size	18340.690	3	18358.676	449.830	0.000
Gear + stream depth	18340.690	3	18417.276	508.430	0.000
Stream segment + current velocity	18539.410	11	18561.479	652.633	0.000
Stream segment + rock size	18541.530	11	18565.849	657.003	0.000
Stream segment + stream depth	18546.490	11	18568.559	659.713	0.000
Stream segment + stream width	18556.020	11	18578.089	669.243	0.000
Site saturated	18731.880	20	18772.100	863.253	0.000

Table 4. Candidate capture efficiency models and associated model selection statistics for captures of mottled sculpin with parallel wire and backpack electrofishing gears at 10 paired sites (upper Greenbrier River drainage, WV) for the first (A), cumulative-second (B), and cumulative-third (C) sampling occasions including the number of parameters (*K*), the second order adjustment of the Akaike information criterion (AIC_c), difference in AIC_c (Δ_i), and the Akaike weights (w_i) for each model.

A.

Model	–2 log likelihood	*K*	AIC_c	Δ_i	w_i
Gear	9699.810	2	9703.815	0.000	0.884
Gear + rock size	9702.710	3	9708.720	4.905	0.076
Gear + stream width	9704.040	3	9710.050	6.235	0.039
Gear + current velocity	9712.400	3	9718.410	14.595	0.001
Gear + stream depth	9737.170	3	9743.180	39.365	0.000
Stream segment + stream width	9763.690	11	9785.806	81.990	0.000
Stream segment + current velocity	9763.710	11	9785.826	82.010	0.000
Stream segment + rock size	9767.120	11	9789.236	85.420	0.000
Stream segment + stream depth	9767.450	11	9789.566	85.750	0.000
Site saturated	9788.490	20	9828.859	125.044	0.000

B.

Model	–2 log likelihood	*K*	AIC_c	Δ_i	w_i
Gear	9975.880	2	9979.885	0.000	0.517
Gear + rock size	9974.010	3	9980.020	0.135	0.483
Gear + current velocity	10012.410	3	10018.420	38.535	0.000
Gear + stream width	10049.590	3	10055.600	75.715	0.000
Gear + stream depth	10105.080	3	10111.090	131.205	0.000
Stream segment + rock size	10133.940	11	10156.056	176.170	0.000
Stream segment + stream width	10134.070	11	10156.186	176.300	0.000
Stream segment + current velocity	10134.400	11	10156.516	176.630	0.000
Stream segment + stream depth	10135.990	11	10158.106	178.220	0.000
Site saturated	10163.480	20	10203.849	223.964	0.000

C.

Model	–2 log likelihood	*K*	AIC_c	Δ_i	w_i
Gear	10672.420	2	10676.425	0.000	1.000
Gear + rock size	10701.080	3	10707.090	30.665	0.000
Gear + current velocity	10727.960	3	10733.970	57.545	0.000
Gear + stream width	10802.240	3	10808.250	131.825	0.000
Gear + stream depth	10864.820	3	10870.830	194.405	0.000
Stream segment + rock size	10930.260	11	10952.376	275.950	0.000
Stream segment + stream depth	10930.600	11	10952.716	276.290	0.000
Stream segment + current velocity	10931.070	11	10953.186	276.760	0.000
Stream segment + stream width	10931.700	11	10953.816	277.390	0.000
Site saturated	10957.730	20	10998.099	321.674	0.000

Table 5. Species abundances ($\hat{N}$) and capture probabilities ($\hat{p}$) estimated from four-pass removal studies with backpack and parallel wire electrofishing gears at 10 paired sites in the upper Greenbrier River drainage, West Virginia. Total counts from seven and four sampling occasions are provided for adults (A) and juveniles (J) of each species. Abundance estimates, standard error (SE, parenthetic for $\hat{p}$), and lower (LCL) and upper (UCL) 95% confidence limits are provided when four-pass sample sizes exceed 40 individuals. An asterisk adjacent to a four-pass count indicates failure of removal depletion.

Species by stream segment and gear	Total 7-pass	Total 4-pass	$\hat{N}$	SE	LCL	UCL	$\hat{p}_1$	$\hat{p}_2$	$\hat{p}_3$	$\hat{p}_4$
Segment 1 (Knapp Creek)										
Backpack										
Rhinichthys obtusus	178	167	174	5.0	169	192	0.52 (0.04)	0.55 (0.07)	0.55 (0.07)	0.55 (0.07)
Etheostoma flabellare	475	443	476	16.0	456	524	0.66 (0.08)	0.41 (0.07)	0.41 (0.07)	0.41 (0.07)
Cottus bairdi	155	147*	–	–	–	–	–	–	–	–
Parallel Wires										
Rhinichthys obtusus	193	184	200	12.4	188	245	0.66 (0.05)	0.38 (0.11)	0.38 (0.11)	0.38 (0.11)
Etheostoma flabellare	373	338	358	9.6	346	387	0.56 (0.03)	0.49 (0.06)	0.49 (0.06)	0.49 (0.06)
Cottus bairdi	141	130	136	5.2	132	156	0.55 (0.05)	0.52 (0.09)	0.52 (0.09)	0.52 (0.09)
Segment 2 (Galford Run)										
Backpack										
Rhinichthys obtusus	62	58*	–	–	–	–	–	–	–	–
Etheostoma flabellare	334	308	365	58.9	319	611	0.47 (0.08)	0.42 (0.13)	0.42 (0.13)	0.42 (0.13)
Cottus bairdi	223	202	211	6.0	205	233	0.52 (0.04)	0.54 (0.07)	0.54 (0.07)	0.54 (0.07)
Parallel Wires										
Rhinichthys obtusus	132	128	128	0.0	128	128	0.83 (0.03)	0.73 (0.09)	0.86 (0.13)	0.86 (0.13)
Etheostoma flabellare	260	242	245	4.2	243	265	0.66 (0.03)	0.58 (0.06)	0.66 (0.14)	0.66 (0.14)
Cottus bairdi	170	158	159	1.7	158	169	0.57 (0.04)	0.57 (0.06)	0.80 (0.10)	0.80 (0.10)
Segment 3 (Little River of West Fork)										
Backpack										
Rhinichthys obtusus	47	37	–	–	–	–	–	–	–	–
Etheostoma flabellare	233	208	346	110.1	243	756	0.29 (0.10)	0.18 (0.10)	0.18 (0.10)	0.18 (0.10)
Cottus bairdi	120	100	110	8.7	102	144	0.52 (0.06)	0.42 (0.12)	0.42 (0.12)	0.42 (0.12)
Parallel Wires										
Rhinichthys obtusus	100	98	98	1.3	98	107	0.73 (0.05)	0.69 (0.10)	0.69 (0.10)	0.69 (0.10)
Etheostoma flabellare	321	282	292	5.4	286	309	0.51 (0.03)	0.58 (0.05)	0.58 (0.05)	0.58 (0.05)
Cottus bairdi	126	104	110	5.0	105	128	0.26 (0.04)	0.55 (0.07)	0.55 (0.07)	0.55 (0.07)
Segment 4 (West Fork)										
Backpack										
Rhinichthys obtusus	31	28	–	–	–	–	–	–	–	–
Etheostoma flabellare	83	71	135	97.1	78	617	0.24 (0.18)	0.15 (0.16)	0.15 (0.16)	0.15 (0.16)
Cottus bairdi	54	46	49	4.6	46	72	0.61 (0.09)	0.43 (0.18)	0.43 (0.18)	0.43 (0.18)
Parallel Wires										
Rhinichthys obtusus	67	66	65	0.0	65	65	0.94 (0.03)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Etheostoma flabellare	222	212	212	0.0	212	212	0.82 (0.03)	0.86 (0.05)	0.86 (0.05)	0.86 (0.05)
Cottus bairdi	62	58	59	2.2	58	70	0.57 (0.07)	0.59 (0.12)	0.59 (0.12)	0.59 (0.12)

Table 5. continued

Segment 5 (East Fork)										
Backpack										
Rhinichthys obtusus	58	58	58	0.0	58	58	0.66 (0.06)	0.70 (0.10)	0.86 (0.13)	0.86 (0.13)
Etheostoma flabellare	213	201	223	24.8	205	330	0.57 (0.07)	0.40 (0.07)	0.37 (0.20)	0.37 (0.20)
Cottus bairdi	96	85	87	4.0	85	109	0.62 (0.06)	0.55 (0.11)	0.59 (0.24)	0.59 (0.24)
Parallel Wires										
Rhinichthys obtusus	88	85	84	1.6	84	95	0.80 (0.05)	0.53 (0.13)	0.71 (0.25)	0.71 (0.25)
Etheostoma flabellare	160	152	180	37.2	156	354	0.51 (0.11)	0.35 (0.15)	0.30 (0.23)	0.30 (0.23)
Cottus bairdi	67	63*	–	–	–	–	–	–	–	–
Segment 6 (Little River of East Fork)										
Backpack										
Rhinichthys obtusus	82	78	78	1.6	78	89	0.52 (0.06)	0.59 (0.08)	0.76 (0.16)	0.76 (0.16)
Etheostoma flabellare	197	152*	–	–	–	–	–	–	–	–
Cottus bairdi	90	63*	–	–	–	–	–	–	–	–
Parallel Wires										
Rhinichthys obtusus	64	78	60	0.0	60	60	0.67 (0.06)	0.55 (0.11)	0.9 (0.09)	0.9 (0.09)
Etheostoma flabellare	255	221	252	26.7	228	354	0.50 (0.06)	0.29 (0.07)	0.41 (0.16)	0.41 (0.16)
Cottus bairdi	112	87	91	4.8	86	113	0.44 (0.08)	0.44 (0.06)	0.62 (0.17)	0.62 (0.17)
Segment 7 (East Fork)										
Backpack										
Rhinichthys obtusus	56	53	55	2.7	53	68	0.57 (0.07)	0.55 (0.14)	0.55 (0.14)	0.55 (0.14)
Etheostoma flabellare	128	108	125	12.9	113	172	0.42 (0.06)	0.38 (0.11)	0.38 (0.11)	0.38 (0.11)
Cottus bairdi	153	134	144	6.8	137	167	0.42 (0.05)	0.50 (0.08)	0.50 (0.08)	0.50 (0.08)
Parallel Wires										
Rhinichthys obtusus	50	46	46	0.0	46	46	0.78 (0.06)	0.67 (0.12)	0.67 (0.12)	0.67 (0.12)
Etheostoma flabellare	147	138	143	4.2	139	159	0.53 (0.04)	0.56 (0.08)	0.56 (0.08)	0.56 (0.08)
Cottus bairdi	136	120	137	11.4	125	176	0.40 (0.05)	0.41 (0.10)	0.41 (0.10)	0.41 (0.10)
Segment 8 (East Fork)										
Backpack										
Rhinichthys obtusus	20	16	–	–	–	–	–	–	–	–
Etheostoma flabellare	66	56*	–	–	–	–	–	–	–	–
Cottus bairdi	95	77	81	5.9	78	109	0.44 (0.06)	0.40 (0.09)	0.40 (0.09)	0.40 (0.09)
Parallel Wires										
Rhinichthys obtusus	61	57	57	0.0	57	57	0.79 (0.05)	0.83 (0.11)	1.00 (0.00)	1.00 (0.00)
Etheostoma flabellare	105	94*	–	–	–	–	–	–	–	–
Cottus bairdi	94	83	94	16.2	84	173	0.49 (0.10)	0.35 (0.14)	0.39 (0.25)	0.39 (0.25)

Table 5. continued

Segment 9 (East Fork)										
Backpack										
Rhinichthys obtusus	73	64	67	4.0	64	85	0.55 (0.07)	0.50 (0.13)	0.50 (0.13)	0.50 (0.13)
Etheostoma flabellare	91	70	70	0.0	70	70	0.60 (0.06)	0.74 (0.07)	0.74 (0.07)	0.74 (0.07)
Cottus bairdi	85	70	72	2.9	70	85	0.47 (0.06)	0.58 (0.10)	0.58 (0.10)	0.58 (0.10)
Parallel Wires										
Rhinichthys obtusus	49	45*	–	–	–	–	–	–	–	–
Etheostoma flabellare	108	96*	–	–	–	–	–	–	–	–
Cottus bairdi	83	62*	–	–	–	–	–	–	–	–
Segment 10 (Long Run)										
Backpack										
Rhinichthys obtusus	–	–	–	–	–	–	–	–	–	–
Etheostoma flabellare	38	34	–	–	–	–	–	–	–	–
Cottus bairdi	124	116	120	5.8	117	147	0.57 (0.05)	0.48 (0.08)	0.58 (0.19)	0.58 (0.19)
Parallel Wires										
Rhinichthys obtusus	6	6	–	–	–	–	–	–	–	–
Etheostoma flabellare	25	24	–	–	–	–	–	–	–	–
Cottus bairdi	113	101	103	2.9	101	117	0.40 (0.05)	0.45 (0.07)	0.73 (0.12)	0.73 (0.12)

Table 6. Mean capture efficiencies for the three commonly captured species with associated standard errors and lower and upper 95% confidence interval (LCI and UCI).

	Mean Capture Efficiency	Standard Error	LCI	UCI
Parallel wires				
R. obtusus	0.734	0.034	0.668	0.800
E. flabellare	0.538	0.024	0.490	0.585
C. bairdi	0.439	0.031	0.379	0.499
Backpack				
R. obtusus	0.551	0.041	0.472	0.631
E. flabellare	0.493	0.025	0.445	0.541
C. bairdi	0.484	0.031	0.424	0.544

Table 7. Mean capture probabilities for the three commonly captured species with associated standard errors and lower and upper 95% confidence intervals (LCI and UCI).

	Mean capture probability	Standard Error	LCI	UCI
Parallel wires				
R. obtusus	0.775	0.047	0.682	0.868
E. flabellare	0.584	0.049	0.489	0.680
C. bairdi	0.460	0.060	0.343	0.577
Backpack				
R. obtusus	0.564	0.056	0.453	0.675
E. flabellare	0.464	0.088	0.292	0.637
C. bairdi	0.523	0.055	0.414	0.631

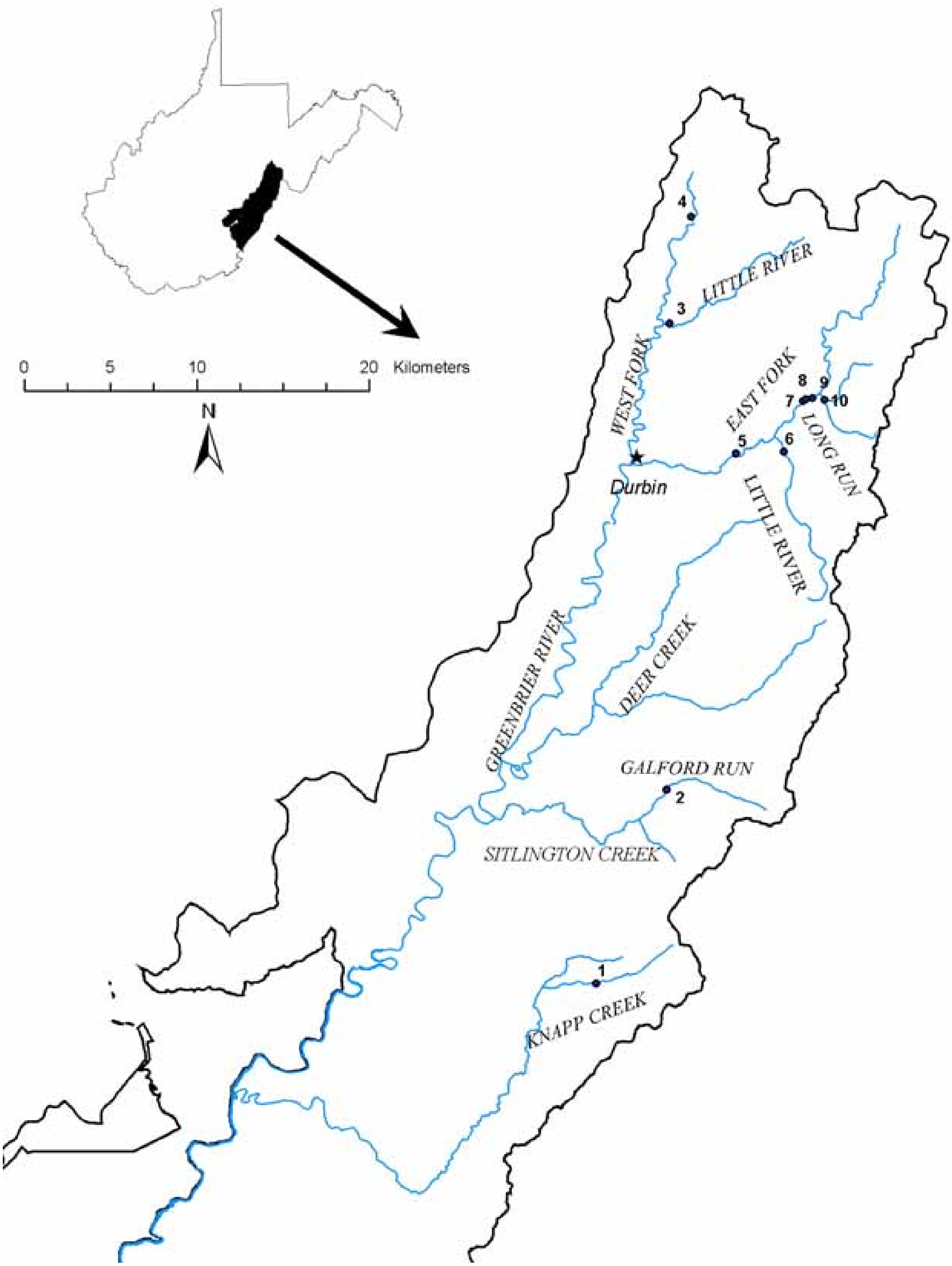


Figure 1. Locations of 10 study reaches (each with two sampling sites) in the upper Greenbrier River drainage, West Virginia, where capture efficiencies and fish abundances were estimated from removal sampling with parallel wire and backpack electrofishing methods.

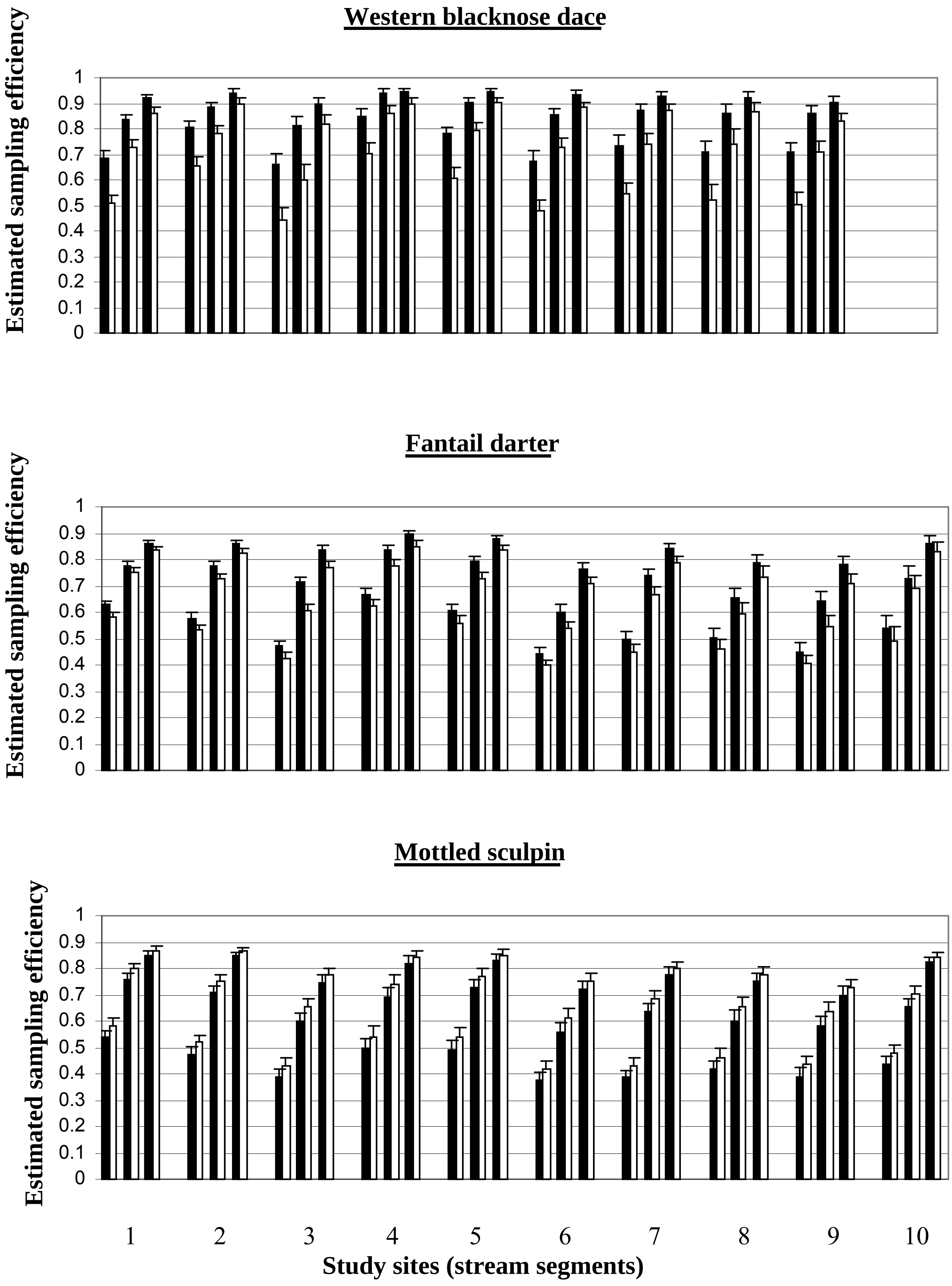
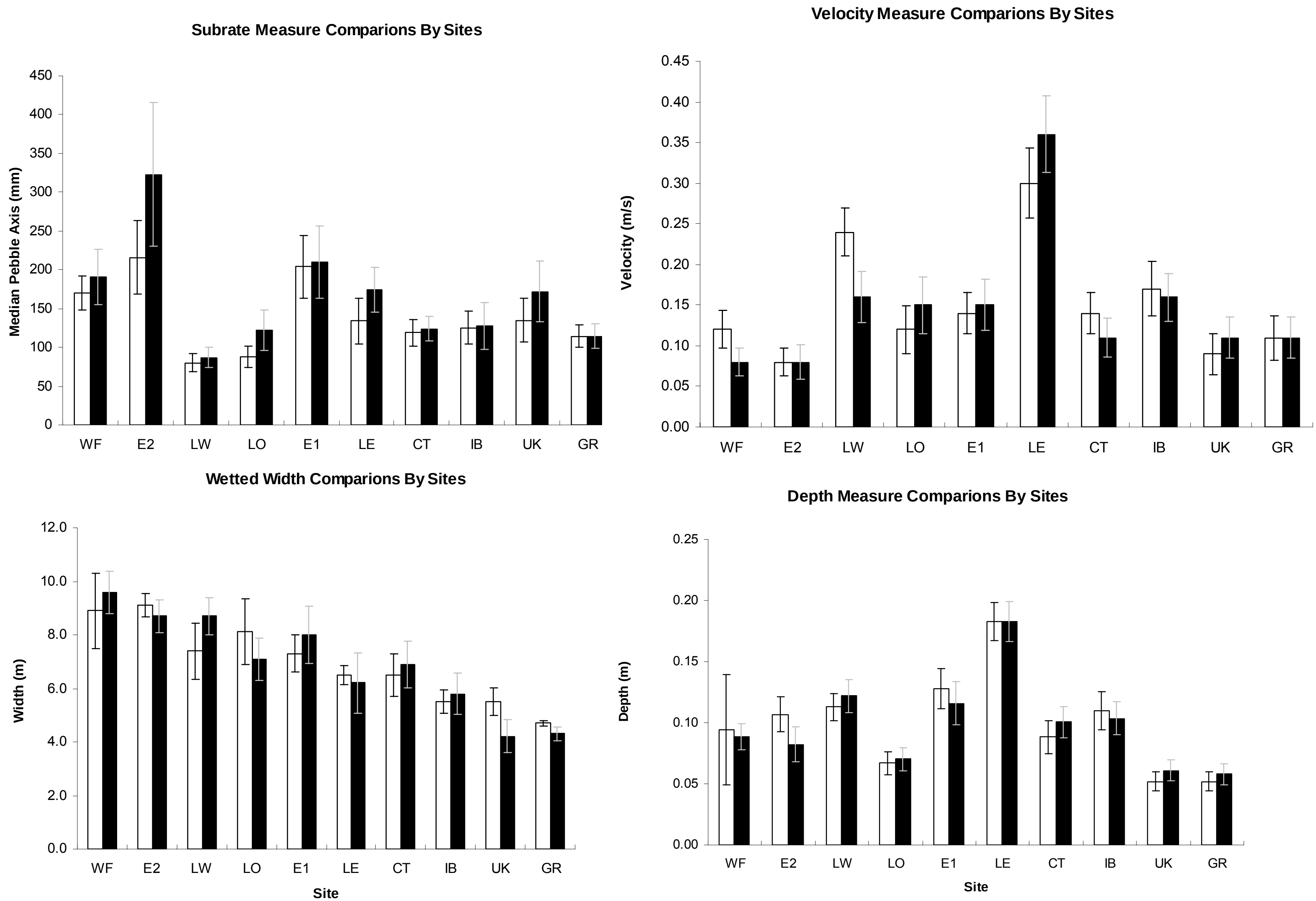


Figure 2. Capture efficiencies of parallel wires (closed) and backpack (open) electrofishers estimated from paired sites within 10 stream segments of the upper Greenbrier River drainage, WV. For each stream segment, estimates for paired sites (adjacent histogram bars) are provided for the first, cumulative-second, and cumulative-third electrofishing sampling occasions.



Appendix 1. Habitat variables (substrate, velocity, wetted width and depth) of parallel wires (closed) and backpack (open) electrofishers estimated from paired sites within 10 stream segments (site acronyms are presented in Appendix 3.1) of the upper Greenbrier River drainage, WV. For each stream segment, habitat averages with 95 % CI are provided for the paired sites (adjacent histogram bars).

Appendix 2. Species abundances ($\hat{N}$) and capture probabilities ($\hat{p}$) estimated from four-pass removal studies with backpack and parallel wire electrofishing gears at 10 paired sites in the upper Greenbrier River drainage, West Virginia. Total counts from seven and four sampling occasions are provided for adults (A) and juveniles (J) of each species. Abundance estimates, standard error (SE, parenthetic for $\hat{p}$), and lower (LCL) and upper (UCL) 95% confidence limits are provided when four-pass sample sizes exceed 40 individuals. An asterisk adjacent to a four-pass count indicates failure of removal depletion. Site descriptions given in Appendix 3.1.

Species by stream segment and gear	Age	Total 7-pass	Total 4-pass	$\hat{N}$	SE	LCL	UCL	$\hat{p}_1$	$\hat{p}_2$	$\hat{p}_3$	$\hat{p}_4$
Segment 1 (Knapp Creek)											
Backpack											
Campostoma anomalum	A	7	7	–	–	–	–	–	–	–	–
Cottus bairdi	A	155	147*	–	–	–	–	–	–	–	–
Cottus bairdi	J	32	26	–	–	–	–	–	–	–	–
Etheostoma caeruleum	A	4	4	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	475	443	476	16.0	524	456	0.66 (0.08)	0.41 (0.07)	0.41 (0.07)	0.41 (0.07)
Etheostoma flabellare	J	28	18	–	–	–	–	–	–	–	–
Notropis telescopus	A	4	4	–	–	–	–	–	–	–	–
Phoxinus oreas	A	21	21	–	–	–	–	–	–	–	–
Phoxinus oreas	J	1	1	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	178	167	174	5.0	192	169	0.52 (0.04)	0.55 (0.07)	0.55 (0.07)	0.55 (0.07)
Rhinichthys obtusus	J	14	10	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	1	1	–	–	–	–	–	–	–	–
Semotilus atromaculatus	A	3	3	–	–	–	–	–	–	–	–
Semotilus atromaculatus	J	5	4	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	128	119	139	16.8	202	124	0.50 (0.07)	0.33 (0.12)	0.33 (0.12)	0.33 (0.12)
Campostoma anomalum	J	4	3	–	–	–	–	–	–	–	–
Cottus bairdi	A	141	130	136	5.2	156	132	0.55 (0.05)	0.52 (0.09)	0.52 (0.09)	0.52 (0.09)
Cottus bairdi	J	15	11	–	–	–	–	–	–	–	–
Etheostoma caeruleum	A	1	1	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	373	338	358	9.6	387	346	0.56 (0.03)	0.49 (0.06)	0.49 (0.06)	0.49 (0.06)
Etheostoma flabellare	J	17	16	–	–	–	–	–	–	–	–
Notropis telescopus	A	16	16	–	–	–	–	–	–	–	–
Phoxinus oreas	A	55	53	53	0.0	53	53	0.77 (0.06)	0.67 (0.11)	0.67 (0.11)	0.67 (0.11)
Rhinichthys obtusus	A	193	184	200	12.4	245	188	0.66 (0.05)	0.38 (0.11)	0.38 (0.11)	0.38 (0.11)
Rhinichthys obtusus	J	1	1	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	1	1	–	–	–	–	–	–	–	–
Semotilus atromaculatus	A	2	1	–	–	–	–	–	–	–	–
Segment 2 (Galford Run)											
Backpack											
Campostoma anomalum	A	9	7	–	–	–	–	–	–	–	–
Campostoma anomalum	J	1	1	–	–	–	–	–	–	–	–
Cottus bairdi	A	223	202	211	6.0	233	205	0.52 (0.04)	0.54 (0.07)	0.54 (0.07)	0.54 (0.07)

Appendix 2. continued.

Cottus bairdi	J	99	78*	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	334	308	365	58.9	611	319	0.47 (0.08)	0.42 (0.13)	0.42 (0.13)	0.42 (0.13)
Etheostoma flabellare	J	50	40	45	11.3	109	40	0.40 (0.12)	0.47 (0.22)	0.36 (0.34)	0.36 (0.34)
Rhinichthys obtusus	A	62	58*	–	–	–	–	–	–	–	–
Rhinichthys obtusus	J	34	30	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	49	49	–	–	–	–	–	–	–	–
Campostoma anomalum	J	26	26	–	–	–	–	–	–	–	–
Cottus bairdi	A	170	158	159	1.7	169	158	0.57 (0.04)	0.57 (0.06)	0.80 (0.10)	0.80 (0.10)
Cottus bairdi	J	97	80	97	25.9	225	82	0.34 (0.10)	0.41 (0.18)	0.32 (0.26)	0.32 (0.26)
Etheostoma flabellare	A	260	242	245	4.2	265	243	0.66 (0.03)	0.58 (0.06)	0.66 (0.14)	0.66 (0.14)
Etheostoma flabellare	J	58	53*	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	132	128	128	0.0	128	128	0.83 (0.03)	0.73 (0.09)	0.86 (0.13)	0.86 (0.13)
Rhinichthys obtusus	J	35	35	–	–	–	–	–	–	–	–
Segment 3 (Little River of the West Fork)											
Backpack											
Cottus bairdi	A	120	100	110	8.7	144	102	0.52 (0.06)	0.42 (0.12)	0.42 (0.12)	0.42 (0.12)
Cottus bairdi	J	48	34	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	233	208	346	110.1	756	243	0.29 (0.10)	0.18 (0.10)	0.18 (0.10)	0.18 (0.10)
Etheostoma flabellare	J	7	1	–	–	–	–	–	–	–	–
Etheostoma osburni	A	10	9	–	–	–	–	–	–	–	–
Etheostoma osburni	J	1	0	–	–	–	–	–	–	–	–
Lepomis cyanellus	J	2	2	–	–	–	–	–	–	–	–
Notropis telescopus	A	22	15	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	47	37	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	7	7	–	–	–	–	–	–	–	–
Semotilus atromaculatus	A	1	1	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	19	19	–	–	–	–	–	–	–	–
Campostoma anomalum	J	5	5	–	–	–	–	–	–	–	–
Clinostomus funduloides	A	14	12	–	–	–	–	–	–	–	–
Clinostomus funduloides	J	5	5	–	–	–	–	–	–	–	–
Cottus bairdi	A	126	104	110	5.0	128	105	0.26 (0.04)	0.55 (0.07)	0.55 (0.07)	0.55 (0.07)
Cottus bairdi	J	46	34	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	321	282	292	5.4	309	286	0.51 (0.03)	0.58 (0.05)	0.58 (0.05)	0.58 (0.05)
Etheostoma flabellare	J	57	53*	–	–	–	–	–	–	–	–
Etheostoma osburni	A	5	4	–	–	–	–	–	–	–	–
Exoglossum laurae	A	1	1	–	–	–	–	–	–	–	–
Hypentelium nigricans	J	4	3	–	–	–	–	–	–	–	–
Lepomis cyanellus	J	2	2	–	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	10	10	–	–	–	–	–	–	–	–
Notropis telescopus	A	28	28	–	–	–	–	–	–	–	–
Phoxinus oreas	A	35	34	–	–	–	–	–	–	–	–

Appendix 2. continued.

Rhinichthys obtusus	A	100	98	98	1.3	107	98	0.73 (0.05)	0.69 (0.10)	0.69 (0.10)	0.69 (0.10)
Rhinichthys obtusus	J	18	18	—	—	—	—	—	—	—	—
Rhinichthys cataractae	A	4	3	—	—	—	—	—	—	—	—
Semotilus atromaculatus	A	1	1	—	—	—	—	—	—	—	—
Semotilus atromaculatus	J	2	2	—	—	—	—	—	—	—	—
Segment 4 (West Fork)											
Backpack											
Cottus bairdi	A	54	46	49	4.6	46	72	0.61 (0.09)	0.43 (0.18)	0.43 (0.18)	0.43 (0.18)
Cottus bairdi	J	2	2	—	—	—	—	—	—	—	—
Etheostoma flabellare	A	83	71	135	97.1	617	78	0.24 (0.18)	0.15 (0.16)	0.15 (0.16)	0.15 (0.16)
Etheostoma flabellare	J	1	1	—	—	—	—	—	—	—	—
Etheostoma osburni	A	6	6	—	—	—	—	—	—	—	—
Nocomis platyrhynchus	A	1	0	—	—	—	—	—	—	—	—
Rhinichthys obtusus	A	31	28	—	—	—	—	—	—	—	—
Rhinichthys obtusus	J	1	1	—	—	—	—	—	—	—	—
Rhinichthys cataractae	A	5	4	—	—	—	—	—	—	—	—
Salmo trutta	A	1	1	—	—	—	—	—	—	—	—
Salmo trutta	J	1	1	—	—	—	—	—	—	—	—
Semotilus atromaculatus	J	3	2	—	—	—	—	—	—	—	—
Parallel Wires											
Cottus bairdi	A	62	58	59	2.2	70	58	0.57 (0.07)	0.59 (0.12)	0.59 (0.12)	0.59 (0.12)
Cottus bairdi	J	5	3	—	—	—	—	—	—	—	—
Etheostoma flabellare	A	222	212	212	0.0	212	212	0.82 (0.03)	0.86 (0.05)	0.86 (0.05)	0.86 (0.05)
Etheostoma flabellare	J	6	6	—	—	—	—	—	—	—	—
Notropis telescopus	A	1	1	—	—	—	—	—	—	—	—
Phoxinus oreas	A	1	1	—	—	—	—	—	—	—	—
Rhinichthys obtusus	A	67	66	65	0.0	65	65	0.94 (0.03)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Rhinichthys obtusus	J	3	2	—	—	—	—	—	—	—	—
Semotilus atromaculatus	J	1	0	—	—	—	—	—	—	—	—
Segment 5 (East Fork)											
Backpack											
Campostoma anomalum	A	188	184	187	5.6	216	184	0.78 (0.04)	0.54 (0.11)	0.54 (0.24)	0.54 (0.24)
Campostoma anomalum	J	66	63	63	2.0	77	63	0.71 (0.06)	0.60 (0.13)	0.66 (0.29)	0.66 (0.29)
Clinostomus funduloides	A	1	1	—	—	—	—	—	—	—	—
Cottus bairdi	A	96	85	87	4.0	109	85	0.62 (0.06)	0.55 (0.11)	0.59 (0.24)	0.59 (0.24)
Cottus bairdi	J	103	90*	—	—	—	—	—	—	—	—
Ehteostoma blennioides	A	1	1	—	—	—	—	—	—	—	—
Etheostoma flabellare	A	213	201	223	24.8	330	205	0.57 (0.07)	0.40 (0.07)	0.37 (0.20)	0.37 (0.20)
Etheostoma flabellare	J	9	8	—	—	—	—	—	—	—	—
Etheostoma osburni	A	16	14	—	—	—	—	—	—	—	—
Etheostoma osburni	J	1	1	—	—	—	—	—	—	—	—
Hypentelium nigricans	J	1	1	—	—	—	—	—	—	—	—

Appendix 2. continued.

Nocomis platyrhynchus	A	3	3	–	–	–	–	–	–	–	–
Nocomis platyrhynchus	J	21	21	–	–	–	–	–	–	–	–
Notropis rubellus	A	35	35	–	–	–	–	–	–	–	–
Notropis rubellus	J	1	1	–	–	–	–	–	–	–	–
Notropis scabriceps	A	9	9	–	–	–	–	–	–	–	–
Notropis telescopus	A	22	21	–	–	–	–	–	–	–	–
Notropis telescopus	J	16	16	–	–	–	–	–	–	–	–
Phenacobius teretulus	A	9	9	–	–	–	–	–	–	–	–
Phenacobius teretulus	J	2	2	–	–	–	–	–	–	–	–
Phoxinus oreas	A	58	57	63	2.0	77	63	0.58 (0.07)	0.63 (0.10)	0.82 (0.12)	0.82 (0.12)
Phoxinus oreas	J	14	12	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	20	18	–	–	–	–	–	–	–	–
Rhinichthys cataractae	J	2	2	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	58	58	58	0.0	58	58	0.66 (0.06)	0.70 (0.10)	0.86 (0.13)	0.86 (0.13)
Rhinichthys obtusus	J	22	20	–	–	–	–	–	–	–	–
Salmo trutta	J	12	11	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	155	150	153	5.8	182	150	0.82 (0.04)	0.35 (0.11)	0.54 (0.24)	0.54 (0.24)
Campostoma anomalum	J	60	50*	–	–	–	–	–	–	–	–
Cottus bairdi	A	67	63*	–	–	–	–	–	–	–	–
Cottus bairdi	J	49	44*	–	–	–	–	–	–	–	–
Ehteostoma blennioides	A	1	1	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	160	152	180	37.2	354	156	0.51 (0.11)	0.35 (0.15)	0.30 (0.23)	0.30 (0.23)
Etheostoma flabellare	J	8	8	–	–	–	–	–	–	–	–
Etheostoma osburni	A	17	17	–	–	–	–	–	–	–	–
Exoglossum laurae	A	4	4	–	–	–	–	–	–	–	–
Exoglossum laurae	J	8	8	–	–	–	–	–	–	–	–
Hypentelium nigricans	J	1	1	–	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	5	5	–	–	–	–	–	–	–	–
Nocomis platyrhynchus	J	39	38	–	–	–	–	–	–	–	–
Notropis rubellus	A	5	5	–	–	–	–	–	–	–	–
Notropis scabriceps	A	8	8	–	–	–	–	–	–	–	–
Notropis telescopus	A	13	13	–	–	–	–	–	–	–	–
Notropis telescopus	J	6	6	–	–	–	–	–	–	–	–
Phenacobius teretulus	A	2	2	–	–	–	–	–	–	–	–
Phenacobius teretulus	J	1	1	–	–	–	–	–	–	–	–
Phoxinus oreas	A	135	131	131	0.0	131	131	0.86 (0.03)	0.79 (0.09)	0.80 (0.18)	0.80 (0.18)
Phoxinus oreas	J	29	27	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	16	16	–	–	–	–	–	–	–	–
Rhinichthys cataractae	J	5	4	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	88	85	84	1.6	95	84	0.80 (0.05)	0.53 (0.13)	0.71 (0.25)	0.71 (0.25)
Rhinichthys obtusus	J	34	33	–	–	–	–	–	–	–	–
Salmo trutta	J	2	2	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	1	1	–	–	–	–	–	–	–	–

Appendix 2. continued.

Segment 6 (Little River of East Fork)											
Backpack											
Campostoma anomalum	A	15	15	–	–	–	–	–	–	–	–
Campostoma anomalum	J	3	3	–	–	–	–	–	–	–	–
Cottus bairdi	A	90	71*	–	–	–	–	–	–	–	–
Cottus bairdi	J	58	38	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	197	152*	–	–	–	–	–	–	–	–
Etheostoma flabellare	J	38	26	–	–	–	–	–	–	–	–
Etheostoma osburni	A	9	9	–	–	–	–	–	–	–	–
Etheostoma osburni	J	2	2	–	–	–	–	–	–	–	–
Exoglossum laurae	A	1	1	–	–	–	–	–	–	–	–
Micropterus salmoides	J	2	1	–	–	–	–	–	–	–	–
Phoxinus oreas	A	13	12	–	–	–	–	–	–	–	–
Phoxinus oreas	J	4	4	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	82	78	78	1.6	89	78	0.52 (0.06)	0.59 (0.08)	0.76 (0.16)	0.76 (0.16)
Rhinichthys obtusus	J	10	8	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	3	3	–	–	–	–	–	–	–	–
Salmo trutta	J	2	2	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	15	15	–	–	–	–	–	–	–	–
Campostoma anomalum	J	3	2	–	–	–	–	–	–	–	–
Cottus bairdi	A	112	87	91	4.8	113	86	0.44 (0.08)	0.44 (0.06)	0.62 (0.17)	0.62 (0.17)
Cottus bairdi	J	49	36	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	255	221	252	26.7	354	228	0.50 (0.06)	0.29 (0.07)	0.41 (0.16)	0.41 (0.16)
Etheostoma flabellare	J	29	19	–	–	–	–	–	–	–	–
Etheostoma osburni	A	4	3	–	–	–	–	–	–	–	–
Etheostoma osburni	J	2	2	–	–	–	–	–	–	–	–
Lepomis auritus	A	1	1	–	–	–	–	–	–	–	–
Phoxinus oreas	A	12	12	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	64	60	60	0.0	60	60	0.67 (0.06)	0.55 (0.11)	0.9 (0.09)	0.9 (0.09)
Rhinichthys obtusus	J	7	7	–	–	–	–	–	–	–	–
Salmo trutta	J	1	1								
Salvelinus fontinalis	J	1	1	–	–	–	–	–	–	–	–
Segment 7 (East Fork)											
Backpack											
Campostoma anomalum	A	13	13	–	–	–	–	–	–	–	–
Cottus bairdi	A	153	134	144	6.8	167	137	0.42 (0.05)	0.50 (0.08)	0.50 (0.08)	0.50 (0.08)
Cottus bairdi	J	63	51	73	26.9	194	54	0.27 (0.11)	0.25 (0.16)	0.25 (0.16)	0.25 (0.16)
Etheostoma flabellare	A	128	108	125	12.9	172	113	0.42 (0.06)	0.38 (0.11)	0.38 (0.11)	0.38 (0.11)
Etheostoma flabellare	J	7	6	–	–	–	–	–	–	–	–
Etheostoma osburni	A	1	1	–	–	–	–	–	–	–	–
Phoxinus oreas	A	1	1	–	–	–	–	–	–	–	–

Appendix 2. continued.

Rhinichthys cataractae	A	8	7	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	56	53	55	2.7	68	53	0.57 (0.07)	0.55 (0.14)	0.55 (0.14)	0.55 (0.14)
Rhinichthys obtusus	J	10	6	–	–	–	–	–	–	–	–
Salmo trutta	A	4	3	–	–	–	–	–	–	–	–
Salmo trutta	J	15	15	–	–	–	–	–	–	–	–
Salvelinus fontinalis	A	1	1	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	2	2	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	21	21	–	–	–	–	–	–	–	–
Campostoma anomalum	J	1	1	–	–	–	–	–	–	–	–
Cottus bairdi	A	136	120	137	11.4	176	125	0.40 (0.05)	0.41 (0.10)	0.41 (0.10)	0.41 (0.10)
Cottus bairdi	J	80	67*	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	147	138	143	4.2	159	139	0.53 (0.04)	0.56 (0.08)	0.56 (0.08)	0.56 (0.08)
Etheostoma flabellare	J	16	15	–	–	–	–	–	–	–	–
Etheostoma osburni	A	1	1	–	–	–	–	–	–	–	–
Phoxinus oreas	A	5	5	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	8	7	–	–	–	–	–	–	–	–
Rhinichthys cataractae	J	1	1	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	50	46	46	0.0	46	46	0.78 (0.06)	0.67 (0.12)	0.67 (0.12)	0.67 (0.12)
Rhinichthys obtusus	J	3	3	–	–	–	–	–	–	–	–
Salmo trutta	J	9	9	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	2	2	–	–	–	–	–	–	–	–
Segment 8 (East Fork)											
Backpack											
Campostoma anomalum	A	2	1	–	–	–	–	–	–	–	–
Cottus bairdi	A	95	77	81	5.9	109	78	0.44 (0.06)	0.40 (0.09)	0.40 (0.09)	0.40 (0.09)
Cottus bairdi	J	20	16	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	66	56*	–	–	–	–	–	–	–	–
Etheostoma flabellare	J	4	3	–	–	–	–	–	–	–	–
Etheostoma osburni	A	1	1	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	6	6	–	–	–	–	–	–	–	–
Rhinichthys cataractae	J	3	2	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	20	16	–	–	–	–	–	–	–	–
Rhinichthys obtusus	J	2	2	–	–	–	–	–	–	–	–
Salmo trutta	A	11	11	–	–	–	–	–	–	–	–
Salmo trutta	J	5	4	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	1	1	–	–	–	–	–	–	–	–
Cottus bairdi	A	94	83	94	16.2	173	84	0.49 (0.10)	0.35 (0.14)	0.39 (0.25)	0.39 (0.25)
Cottus bairdi	J	76	63*	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	105	94*	–	–	–	–	–	–	–	–
Etheostoma flabellare	J	11	9	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	9	7	–	–	–	–	–	–	–	–

Appendix 2. continued

Rhinichthys cataractae	J	1	1	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	61	57	57	0.0	57	57	0.79 (0.05)	0.83 (0.11)	1.00 (0.00)	1.00 (0.00)
Salmo trutta	A	3	3	–	–	–	–	–	–	–	–
Salmo trutta	J	4	2	–	–	–	–	–	–	–	–
Salvelinus fontinalis	A	1	1	–	–	–	–	–	–	–	–
Segment 9 (East Fork)											
Backpack											
Campostoma anomalum	A	11	10	–	–	–	–	–	–	–	–
Campostoma anomalum	J	1	1	–	–	–	–	–	–	–	–
Cottus bairdi	A	85	70	72	2.9	85	70	0.47 (0.06)	0.58 (0.10)	0.58 (0.10)	0.58 (0.10)
Cottus bairdi	J	39	25	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	91	70	70	0.0	70	70	0.60 (0.06)	0.74 (0.07)	0.74 (0.07)	0.74 (0.07)
Etheostoma flabellare	J	4	0	–	–	–	–	–	–	–	–
Exoglossum laurae	A	1	1	–	–	–	–	–	–	–	–
Notropis rubellus	A	1	0	–	–	–	–	–	–	–	–
Phoxinus oreas	A	4	4	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	4	4	–	–	–	–	–	–	–	–
Rhinichthys cataractae	J	1	1	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	73	64	67	4.0	85	64	0.55 (0.07)	0.50 (0.13)	0.50 (0.13)	0.50 (0.13)
Salmo trutta	A	4	4	–	–	–	–	–	–	–	–
Salmo trutta	J	4	4	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	1	1	–	–	–	–	–	–	–	–
Parallel Wires											
Campostoma anomalum	A	21	20	–	–	–	–	–	–	–	–
Cottus bairdi	A	83	62*	–	–	–	–	–	–	–	–
Cottus bairdi	J	31	26	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	108	96*	–	–	–	–	–	–	–	–
Hypentelium nigricans	A	1	1	–	–	–	–	–	–	–	–
Oncorhynchus mykiss	A	1	1	–	–	–	–	–	–	–	–
Phoxinus oreas	A	2	2	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	4	3	–	–	–	–	–	–	–	–
Rhinichthys obtusus	A	49	45*	–	–	–	–	–	–	–	–
Salmo trutta	A	5	5	–	–	–	–	–	–	–	–
Salmo trutta	J	8	7	–	–	–	–	–	–	–	–
Salvelinus fontinalis	A	1	1	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	1	1	–	–	–	–	–	–	–	–
Segment 10 (Long Run)											
Backpack											
Cottus bairdi	A	124	116	120	5.8	147	117	0.57 (0.05)	0.48 (0.08)	0.58 (0.19)	0.58 (0.19)
Cottus bairdi	J	11	9	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	38	34	–	–	–	–	–	–	–	–
Salmo trutta	J	13	13	–	–	–	–	–	–	–	–

Appendix 2. continued.

Salvelinus fontinalis	J	4	3	–	–	–	–	–	–	–	–
Parallel Wires											
Rhinichthys obtusus	A	6	101	–	–	–	–	–	–	–	–
Rhinichthys cataractae	A	1	5	–	–	–	–	–	–	–	–
Cottus bairdi	A	113	24	103	2.9	117	101	0.40 (0.05)	0.45 (0.07)	0.73 (0.12)	0.73 (0.12)
Cottus bairdi	J	5	6	–	–	–	–	–	–	–	–
Etheostoma flabellare	A	25	1	–	–	–	–	–	–	–	–
Salmo trutta	J	7	7	–	–	–	–	–	–	–	–
Salvelinus fontinalis	J	9	9	–	–	–	–	–	–	–	–

Appendix 3. Fish distributions in the Greenbrier River, West Virginia

Sites were sampled in the Greenbrier River drainage in summer and fall of 2005-2006. Study objective were to estimate abundances of sensitive species, specifically the four New River endemics: candy darter, Kanawha minnow, New River shiner and Appalachia darter. Qualitative and quantitative methods were used in this collection. I sampled fifteen 150 m sites with three sampling occasions, except one double pass site with a parallel wire unit modified from the Holton and Sullivan (1954) design and described in chapter two of this thesis. Eleven qualitative sites were sampled in locations where stream conditions were to wide to permit extensive sampling or in areas of special interest. Qualitative sites were sampled with a Smith-Root® backpack unit (Model 12B) for a minimum of 15 minutes at each location. Chapter 2 described a comparison study where some sensitive fish species were captured and these sites are included. In this appendix I provide maps and tables of the locations of sensitive fishes captured in this two year study. I also include a table of all fish species captured at the 150 m sites. I list population estimates, standard errors, 95% confidence intervals and capture probabilities for fish species and age classes with >40 individuals captured. Total number captured is listed for all species with <40 individuals.

Appendix 3.1 Streams sampled in 2005-2006 with site descriptions and UTM NAD 27 coordinates.

STREAM		SITE DESCRIPTION	UTMEW	UTMNS
150 meter sites				
A1	West Fork	0.35 km N of the confluence of Elklick Run and 3 km N May, WV	605440	4281040
A2	Knapp Creek	at Herold farm pasture on Rt 92, approximately 2 km S Frost, WV	596232	4235035
A3	Little River of East Fork	on Rt. 250, approximately 1.25 km E of the 28/250 junction, 2 km E Thornwood, WV	610925	4266923
A4	Sitlington Creek	on Rt. 92, approximately 2.7 km S of the 92/28 junction in Dunmore, WV	599970	4244535
A5	Knapp Creek	on Camp Minnehaha property at Minnehaha Springs, WV	589553	4224219
A6	Deer Creek	at Rt. 66 bridge approximately 1 km E of 66/28 junction, 4 km SW Green Bank, WV	598872	4251056
A7	North Fork of Deer Creek	at the 28/92 bridge approximately 2 km SW of Green Bank, WV	599901	4252597
A8	North Fork of Deer Creek	on CR 28-5 bridge on the Clevenger property, Green Bank, WV	602178	4252594
A9	North Fork of Anthony	approximately 2 km N on FR 96 Neola, WV	575891	4204322
A10	Anthony Creek	approximately 0.5 km E of Blue Bend, WV on CR 21-2 at iron bridge	565067	4196893
A11	West Fork	approximately 0.2 km N of the Rt. 250 bridge, Durbin, WV	602012	4267972
A12	East Fork	approximately 1 km S of Camp Pocahontas (28/PR 14 intersection), 6 km N Bartow, WV	611322	4269358
A13	Anthony Creek	approximately 3.5 km E of Blue Bend, WV on CR 21-2	561653	4195970
A14	Anthony Creek	approximately 3.8 km E of Blue Bend, WV on CR 21-2	561312	4196091
A15	Anthony Creek	approximately 2.9 km E of Blue Bend, WV on CR 21-2	561928	4195801

Appendix 3.1 continued.

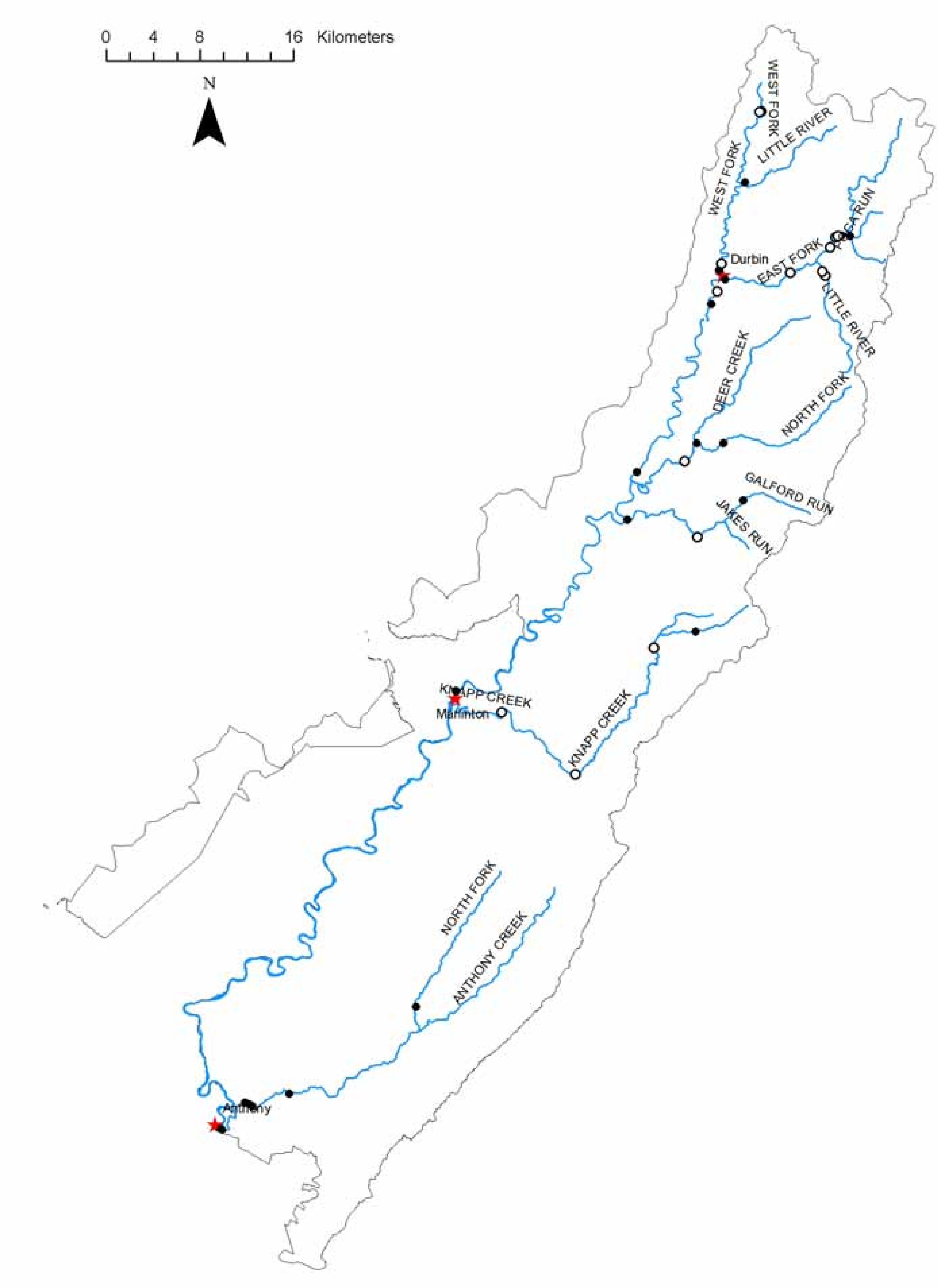
Comparison sites (Chapter 2)

1	Knapp Creek (UK)	approximately 1.9 km E of Frost on Rt. 84	599805	4236414
2	Galford Run (GR)	on Melko property on CR 6-2, approximately 0.7 km E of CR 6/CR 6-2 junction	603889	4247674
3	Little River of West Fork (LW)	approximately 500 m upstream of confluence with West Fork, 1.8 km N Braucher, WV	604046	4274728
4	West Fork (WF)	approximately150 m downstream of A1 (150 meter site)	605303	4280949
5	East Fork (IB)	at the 28-19 bridge, approximately 1.5 km N of Bartow, WV	607920	4267188
6	Little River of East Fork (LE)	on Rt. 250, approximately 0.9 km E of the 28/250 junction	610664	4267301
7	East Fork (CT)	downstream of the Rt 28/PR 14 bridge at Camp Pocahontas, 7 km N Bartow, WV	611789	4270227
8	East Fork (E2)	approximately 0.3 km N of Rt 28/RR 14 Junction at Camp Pocahontas, 7.3 km N Bartow, WV	611976	4270354
9	East Fork (E1)	approximately 0.6 km N of Rt 28/PR 14 Junction at Camp Pocahontas, 7.6 km N Bartow, WV	612327	4270415
10	Long Run (LO)	appproximately 1.1 km N of Camp Pocahontas upstream of Rt. 28 bridge crossing, 8.3 km N Bartow, WV	613035	4270321

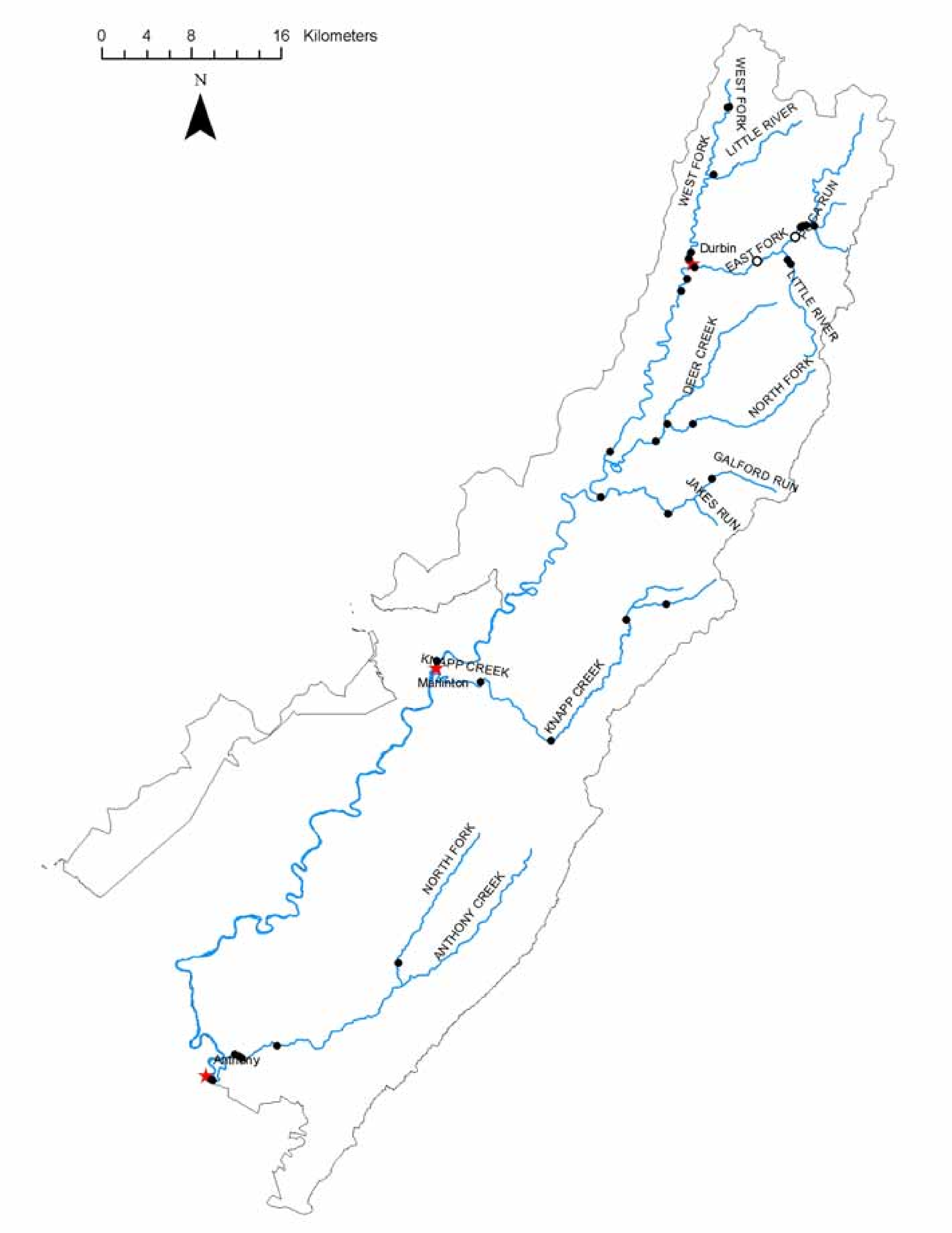
Appendix 3.1 continued.

Qualitative Sampling

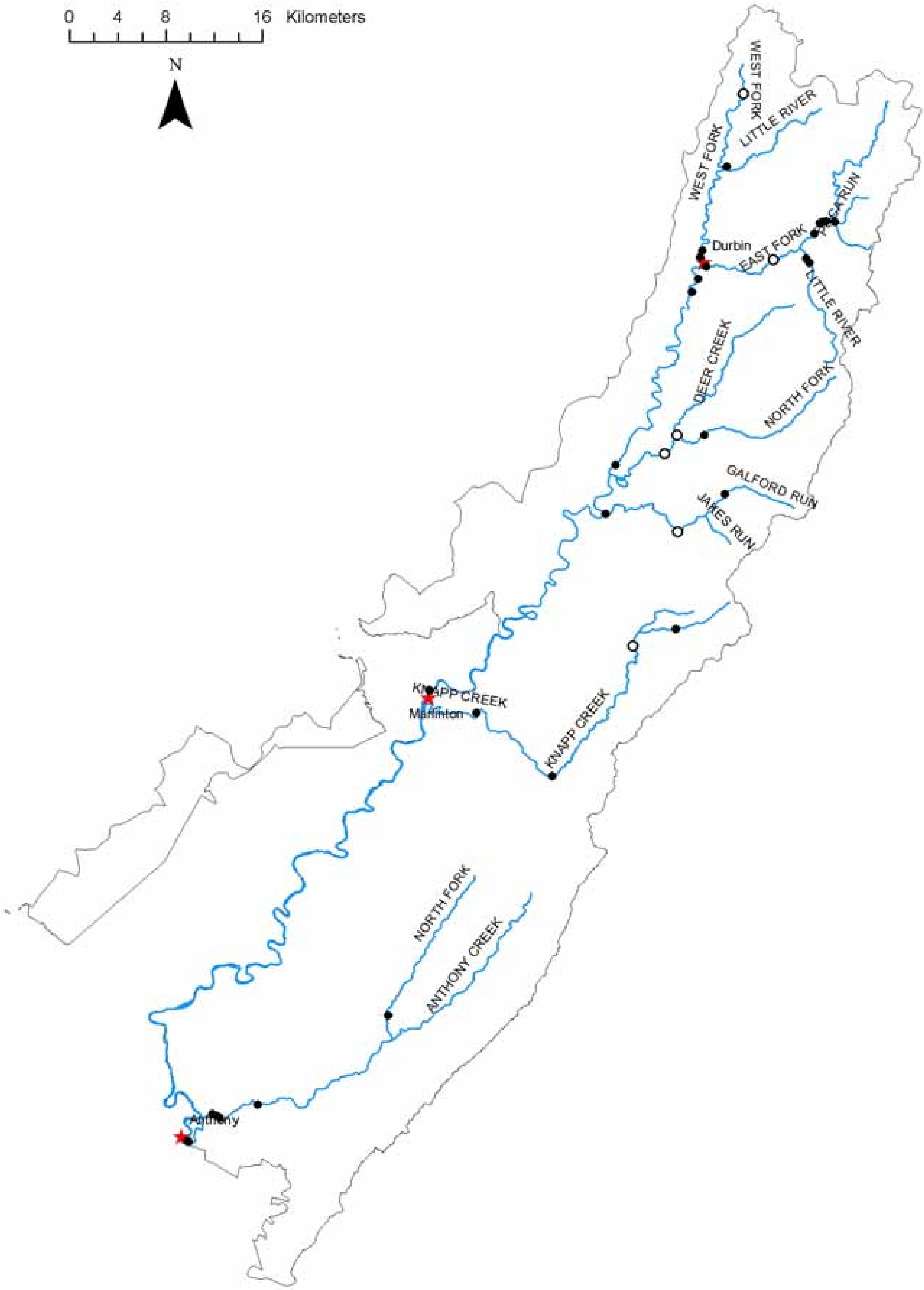
Q1	Anthony Creek	approximately 300 m upstream of confluence with Greenbrier River at Anthony, WV	559352	4193787
Q2	Greenbrier	at confluence with Anthony Creek at Anthony, WV	559262	4193847
Q3	Greenbrier	approximately 0.5 km N of 219/39 junction, Marlinton, WV	579331	4231400
Q4	Knapp Creek	approximately 5 km E of Marlinton, WV on Rt. 39	583268	4229506
Q5	Sitlington Creek	approximately 200 m upstream of confluence with the Greenbrier River	593959	4246010
Q6	Greenbrier	at the Rt. 66 bridge, Cass, WV	594832	4250116
Q7	West Fork	at the CR 250-11 bridge, Durbin, WV	601818	4267376
Q8	Greenbrier	approximately 3 km S of Durbin, WV on CR 250-2	601133	4264505
Q9	Greenbrier	approximately 2 km S of Durbin, WV on CR 250-2	601660	4265601
Q10	East Fork	at East Fork Campground, Durbin, WV	602368	4266632
Q11	East Fork	downstream of 28-19 bridge approximately 1.5 km N of Bartow, WV	607936	4267191



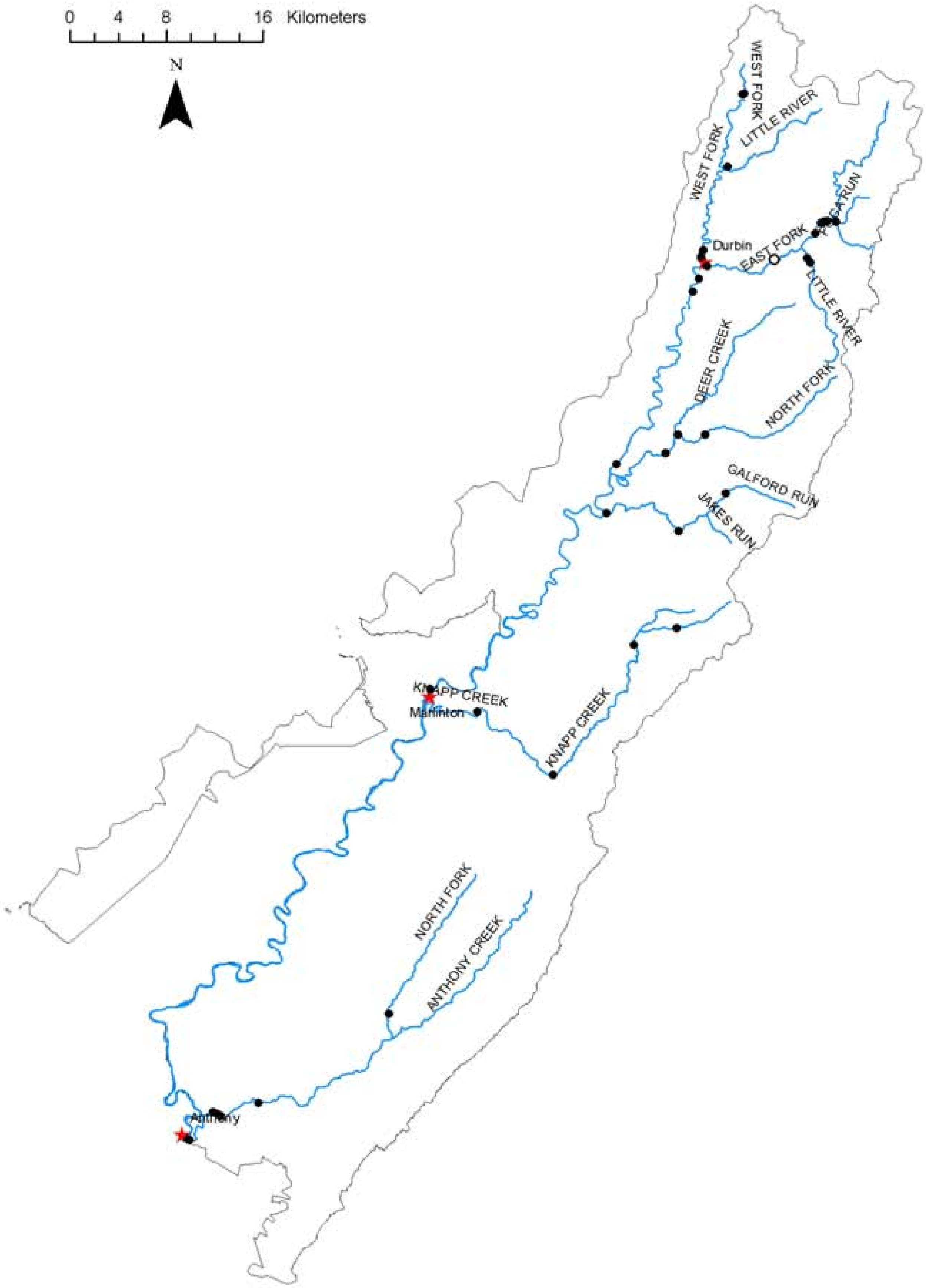
Appendix 3.2 Locations of candy darter captures in 2005-2006 (denoted by open circle).



Appendix 3.3 Locations of Kanawha minnow captures in 2005-2006 (denoted by open circle).



Appendix 3.4 Locations of New River shiner captures in 2005-2006 (denoted by the open circles).



Appendix 3.5 Location of an Appalachia darter capture in 2005-2006 (denoted by the open circle).

Appendix 3.6 Quantitative and qualitative (P) samples (2005-2006) of candy darter, Kanawha minnow, New River shiner and Appalachia darter.

Candy darter

Site ID	Location	Number Collected
A12	East Fork of the Greenbrier	2
A6	Deer Creek	4
A11	West Fork	3
A5	Knapp Creek	6
A2	Knapp Creek	30
A4	Sitlington Creek	20
A3	Little River of East Fork	18
A1	West Fork	8
LW	Little River of West Fork	16
WF	West Fork	6
CT	East Fork	2
IB	East Fork	34
E2	East Fork	1
LE	Little River of East Fork	17
Q4	Knapp Creek	P
Q9	Greenbrier	P
Q11	East Fork	P

Kanawha minnow

Site ID	Location	Number Collected
A12	East Fork	1
IB	East Fork	14
Q11	East Fork	P

New River shiner

Site ID	Location	Number Collected
A7	North Fork of Deer Creek	34
A6	Deer Creek	27
A2	Knapp Creek	177
A4	Sitlington Creek	108
A1	West Fork	12
IB	East Fork	17
Q11	East Fork	P

Appalachia darter

Site ID	Location	Number Collected
Q11	East Fork	P

Appendix 3.7 Species abundances ($\hat{N}$) and capture probabilities ($\hat{p}$) estimated from three-pass removal studies (with the exception of one two-pass site where total counts are provided) with parallel wire electrofishing gears at 15 sites in the Greenbrier River drainage, West Virginia. Total counts from three sampling occasions are provided for adults (A) and juveniles (J) of each species. Abundance estimates, standard error (SE, parenthetic for $\hat{p}$), and lower (LCL) and upper (UCL) 95% confidence limits are provided when three-pass sample sizes exceed 40 individuals. An asterisk adjacent to a three-pass count indicates failure of removal depletion. Site descriptions are in Appendix 3.1.

Species by stream segment and gear	Age	Total 3-pass	$\hat{N}$	SE	LCL	UCL	$\hat{p}_1$	$\hat{p}_2$	$\hat{p}_3$
Site A1									
Ambloplites rupestris	A	10	–	–	–	–	–	–	–
Ambloplites rupestris	J	0	–	–	–	–	–	–	–
Campostoma anomalum	A	21	–	–	–	–	–	–	–
Campostoma anomalus	J	1	–	–	–	–	–	–	–
Cottus bairdi	A	232	380	138.8	263	934	0.33 (0.12)	0.23 (0.15)	0.23 (0.15)
Cottus bairdi	J	14	–	–	–	–	–	–	–
Etheostoma blennioides	A	8	–	–	–	–	–	–	–
Etheostoma blennioides	J	0	–	–	–	–	–	–	–
Etheostoma flabellare	A	583	821	117.4	678	1177	0.40 (0.06)	0.31 (0.09)	0.31 (0.09)
Etheostoma flabellare	J	13	–	–	–	–	–	–	–
Etheostoma osburni	A	7	–	–	–	–	–	–	–
Etheostoma osburni	J	1	–	–	–	–	–	–	–
Exoglossum laurae	A	1	–	–	–	–	–	–	–
Exoglossum laurae	J	5	–	–	–	–	–	–	–
Hypentelium nigricans	A	2	–	–	–	–	–	–	–
Hypentelium nigricans	J	12	–	–	–	–	–	–	–
Nocomis platyrhnchus	A	5	–	–	–	–	–	–	–
Notropis scabriceps	A	9	–	–	–	–	–	–	–
Notropis scabriceps	J	3	–	–	–	–	–	–	–
Notropis telescopus	A	53*	–	–	–	–	–	–	–
Phoxinus oreas	A	11	–	–	–	–	–	–	–
Phoxinus oreas	J	0	–	–	–	–	–	–	–
Rhinichthys obtusus	A	355	366	7.3	358	391	0.75 (0.03)	0.65 (0.09)	0.65 (0.09)
Rhinichthys obtusus	J	18	–	–	–	–	–	–	–
Salmo trutta	A	2	–	–	–	–	–	–	–
Semotilus atromaculatus	A	28	–	–	–	–	–	–	–
Semotilus atromaculatus	J	31	–	–	–	–	–	–	–
Site A2									
Ambloplites rupestris	A	29	–	–	–	–	–	–	–
Ambloplites rupestris	J	35	–	–	–	–	–	–	–
Campostoma anomalum	A	586	586	0.0	586	586	0.91 (0.01)	0.91 (0.01)	0.91 (0.01)
Campostoma anomalus	J	113	114	1.6	113	122	0.76 (0.04)	0.76 (0.04)	0.76 (0.04)
Cottus bairdi	A	47	50	2.7	47	61	0.61 (0.08)	0.61 (0.08)	0.61 (0.08)

Appendix 3.7 continued

Cottus bairdi	J	167	171	2.7	168	180	0.71 (0.04)	0.71 (0.04)	0.71 (0.04)
Etheostoma blennioides	A	34	–	–	–	–	–	–	–
Etheostoma blennioides	J	3	–	–	–	–	–	–	–
Etheostoma caeruleum	A	19	–	–	–	–	–	–	–
Etheostoma caeruleum	J	26	–	–	–	–	–	–	–
Etheostoma flabellare	A	1051	1086	8.2	1073	1105	0.68 (0.02)	0.68 (0.02)	0.68 (0.02)
Etheostoma flabellare	J	260	285	19.4	266	356	0.70 (0.05)	0.46 (0.14)	0.46 (0.14)
Etheostoma osburni	A	28	–	–	–	–	–	–	–
Etheostoma osburni	J	2	–	–	–	–	–	–	–
Hypentelium nigricans	A	10	–	–	–	–	–	–	–
Hypentelium nigricans	J	52	52	0.0	52	52	0.83 (0.05)	0.90 (0.09)	0.90 (0.09)
Lepomis auritus	A	1	–	–	–	–	–	–	–
Lepomis auritus	J	2	–	–	–	–	–	–	–
Luxilus chrysocephalus	A	67*	–	–	–	–	–	–	–
Luxilus chrysocephalus	J	99	112	16.5	101	187	0.65 (0.11)	0.41 (0.22)	0.41 (0.22)
Micropterus dolomieu	A	0	–	–	–	–	–	–	–
Micropterus dolomieu	J	44	44	0.0	44	44	0.84 (0.06)	0.88 (0.12)	0.88 (0.12)
Nocomis leptocephalus	A	77	77	0.1	77	77	0.94 (0.03)	0.71 (0.17)	0.71 (0.17)
Nocomis leptocephalus	J	131	132	2.2	131	145	0.86 (0.03)	0.73 (0.16)	0.73 (0.16)
Notropis telescopus	A	619	818	184.7	661	1552	0.61 (0.14)	0.21 (0.14)	0.21 (0.14)
Notropis telescopus	J	17	–	–	–	–	–	–	–
Notropis rubellus	A	28	–	–	–	–	–	–	–
Notropis scabriceps	A	177	192	16.4	180	262	0.76 (0.72)	0.43 (0.20)	0.43 (0.20)
Notropis volucellus	A	12	–	–	–	–	–	–	–
Percina roanoka	A	7	–	–	–	–	–	–	–
Phoxinus oreas	A	22	–	–	–	–	–	–	–
Phoxinus oreas	J	4	–	–	–	–	–	–	–
Pimephales notatus	A	233*	–	–	–	–	–	–	–
Pimephales notatus	J	6	–	–	–	–	–	–	–
Rhinichthys obtusus	A	5	–	–	–	–	–	–	–
Rhinichthys obtusus	J	7	–	–	–	–	–	–	–
Semotilus atromaculatus	A	62	67	4.3	64	89	0.71 (0.07)	0.60 (0.21)	0.60 (0.21)
Semotilus atromaculatus	J	66	69	4.9	66	89	0.79 (0.07)	0.73 (0.16)	0.73 (0.16)
Site A3									
Campostoma anomalum	A	90	91	2.2	90	104	0.65 (0.06)	0.85 (0.07)	0.85 (0.07)
Campostoma anomalus	J	62	62	0.1	62	62	0.22 (0.52)	0.10 (0.32)	0.10 (0.32)
Catostomus commersoni	A	11	–	–	–	–	–	–	–
Catostomus commersoni	J	42*	–	–	–	–	–	–	–
Cottus bairdi	A	388	403	7.8	394	427	0.58 (0.03)	0.70 (0.06)	0.70 (0.06)
Cottus bairdi	J	162	168	4.8	163	186	0.54 (0.04)	0.71 (0.08)	0.71 (0.08)
Etheostoma blennioides	A	4	–	–	–	–	–	–	–
Etheostoma flabellare	A	1037	1133	33.4	1086	1223	0.66 (0.02)	0.50 (0.06)	0.50 (0.06)
Etheostoma flabellare	J	347	3350	3.2	348	363	0.79 (0.02)	0.77 (0.07)	0.77 (0.07)

Appendix 3.7 continued

Etheostoma osburni	A	16	—	—	—	—	—	—	—
Etheostoma osburni	J	2	—	—	—	—	—	—	—
Exoglossum laurae	A	11	—	—	—	—	—	—	—
Exoglossum laurae	J	5	—	—	—	—	—	—	—
Hypentelium nigricans	A	4	—	—	—	—	—	—	—
Hypentelium nigricans	J	3	—	—	—	—	—	—	—
Lepomis macrochirus	J	2	—	—	—	—	—	—	—
Micropterus salmoides	J	7	—	—	—	—	—	—	—
Oncorhynchus mykiss	A	2	—	—	—	—	—	—	—
Phoxinus oreas	A	329	336	6.0	331	359	0.81 (0.03)	0.65 (0.10)	0.65 (0.10)
Phoxinus oreas	J	7	—	—	—	—	—	—	—
Rhinichthys obtusus	A	494	496	2.1	494	505	0.78 (0.02)	0.85 (0.04)	0.85 (0.04)
Rhinichthys obtusus	J	43	43	1.8	43	55	0.67 (0.08)	0.74 (0.17)	0.74 (0.17)
Rhinichthys cataractae	A	7	—	—	—	—	—	—	—
Rhinichthys cataractae	J	8	—	—	—	—	—	—	—
Salmo trutta	A	6	—	—	—	—	—	—	—
Salmo trutta	J	10	—	—	—	—	—	—	—
Salvelinus fontinalis	A	3	—	—	—	—	—	—	—
Salvelinus fontinalis	J	3	—	—	—	—	—	—	—
Semotilus atromaculatus	A	3	—	—	—	—	—	—	—
Semotilus atromaculatus	J	27	—	—	—	—	—	—	—
Site A4									
Ambloplites rupestris	A	39	—	—	—	—	—	—	—
Ambloplites rupestris	J	4	—	—	—	—	—	—	—
Campostoma anomalum	A	467	476	5.7	470	495	0.78 (0.02)	0.71 (0.07)	0.71 (0.07)
Campostoma anomalum	J	57	60	3.8	57	78	0.57 (0.07)	0.65 (0.16)	0.65 (0.16)
Cottus bairdi	A	222	357	126.1	251	859	0.34 (0.12)	0.24 (0.15)	0.24 (0.15)
Cottus bairdi	J	44	44	0.0	44	44	0.66 (0.07)	0.83 (0.09)	0.83 (0.09)
Cyprinella galactura	A	22	—	—	—	—	—	—	—
Etheostoma blennioides	A	24	—	—	—	—	—	—	—
Etheostoma flabellare	A	484	521	15.8	500	566	0.57 (0.03)	0.59 (0.06)	0.59 (0.06)
Etheostoma flabellare	J	279	285	4.1	281	299	0.59 (0.03)	0.77 (0.06)	0.77 (0.06)
Etheostoma osburni	A	20	—	—	—	—	—	—	—
Exoglossum laurae	J	2	—	—	—	—	—	—	—
Hypentelium nigricans	A	22	—	—	—	—	—	—	—
Hypentelium nigricans	J	9	—	—	—	—	—	—	—
Micropterus dolomieu	A	18	—	—	—	—	—	—	—
Micropterus dolomieu	J	49*	—	—	—	—	—	—	—
Nocomis leptocephalus	A	15	—	—	—	—	—	—	—
Nocomis leptocephalus	J	21	—	—	—	—	—	—	—
Nocomis platyrhynchus	A	34	—	—	—	—	—	—	—
Nocomis platyrhynchus	J	2	—	—	—	—	—	—	—
Notropis scabriceps	A	108	109	1.6	108	118	0.70 (0.05)	0.82 (0.09)	0.82 (0.09)

Appendix 3.7 continued

Notropis scabriceps	J	1	–	–	–	–	–	–	–
Notropis telescopus	A	995	1076	1.6	1034	1166	0.70 (0.03)	0.49 (0.07)	0.49 (0.07)
Notropis telescopus	J	56	56	0.0	56	56	0.80 (0.05)	0.92 (0.08)	0.92 (0.08)
Phoxinus oreas	A	1	–	–	–	–	–	–	–
Pimephales notatus	A	4	–	–	–	–	–	–	–
Rhinichthys obtusus	A	28	–	–	–	–	–	–	–
Rhinichthys obtusus	J	11	–	–	–	–	–	–	–
Semotilus atromaculatus	J	5	–	–	–	–	–	–	–
Site A5									
Ambloplites rupestris	A	37	–	–	–	–	–	–	–
Ambloplites rupestris	J	35	–	–	–	–	–	–	–
Campostoma anomalum	A	738	739	1.5	738	746	0.86 (0.01)	0.86 (0.01)	0.86 (0.01)
Campostoma anomalus	J	93	93	0.0	93	93	0.81 (0.03)	0.81 (0.03)	0.81 (0.03)
Cottus bairdi	A	30	–	–	–	–	–	–	–
Cottus bairdi	J	9	–	–	–	–	–	–	–
Cyprinella galactura	A	160*	–	–	–	–	–	–	–
Cyprinella galactura	J	64	66	2.4	64	76	0.65 (0.07)	0.65 (0.07)	0.65 (0.07)
Etheostoma blennioides	A	3	–	–	–	–	–	–	–
Etheostoma blennioides	J	1	–	–	–	–	–	–	–
Etheostoma caeruleum	A	277	317	13.4	298	353	0.50 (0.04)	0.50 (0.04)	0.50 (0.04)
Etheostoma caeruleum	J	82	103	2.7	89	145	0.41 (0.09)	0.41 (0.09)	0.41 (0.09)
Etheostoma flabellare	A	159	175	7.3	166	196	0.55 (0.05)	0.55 (0.05)	0.55 (0.05)
Etheostoma flabellare	J	71*	–	–	–	–	–	–	–
Etheostoma osburni	A	6	–	–	–	–	–	–	–
Hypentelium nigricans	A	3	–	–	–	–	–	–	–
Hypentelium nigricans	J	22	–	–	–	–	–	–	–
Lepomis auritus	A	14	–	–	–	–	–	–	–
Lepomis auritus	J	50	50	0.1	50	50	0.83 (0.05)	0.83 (0.05)	0.83 (0.05)
Luxilus chrysocephalus	A	11	–	–	–	–	–	–	–
Luxilus chrysocephalus	J	14	–	–	–	–	–	–	–
Micropterus dolomieu	A	6	–	–	–	–	–	–	–
Micropterus dolomieu	J	51	51	1.3	51	59	0.74 (0.07)	0.74 (0.07)	0.74 (0.07)
Nocomis leptocephalus	A	79	79	0.6	79	82	0.81 (0.04)	0.81 (0.04)	0.81 (0.04)
Nocomis leptocephalus	J	51*	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	16	–	–	–	–	–	–	–
Nocomis platyrhynchus	J	29	–	–	–	–	–	–	–
Notropis telescopus	A	428	445	6.0	437	461	0.66(0.03)	0.66(0.03)	0.66(0.03)
Notropis telescopus	J	410*	–	–	–	–	–	–	–
Percina roanoka	A	57*	–	–	–	–	–	–	–
Percina roanoka	J	3	–	–	–	–	–	–	–
Pimephales notatus	A	52	53	1.4	52	61	0.73 (0.07)	0.73 (0.07)	0.73 (0.07)
Pimephales notatus	J	9	–	–	–	–	–	–	–
Semotilus atromaculatus	J	3	–	–	–	–	–	–	–

Appendix 3.7 continued

Site A6									
Ambloplites rupestris	A	7	–	–	–	–	–	–	–
Ambloplites rupestris	J	12	–	–	–	–	–	–	–
Campostoma anomalum	A	1134	1158	9.1	1146	1183	0.72 (0.02)	0.72 (0.04)	0.72 (0.04)
Campostoma anomalus	J	397	416	11.7	403	455	0.73 (0.03)	0.59 (0.09)	0.59 (0.09)
Cottus bairdi	A	643	683	17.3	661	733	0.67 (0.02)	0.58 (0.07)	0.58 (0.07)
Cottus bairdi	J	109	114	4.7	110	133	0.47 (0.05)	0.69 (0.10)	0.69 (0.10)
Cyprinella galactura	A	5	–	–	–	–	–	–	–
Etheostoma blennioides	A	42	42	0.0	42	42	0.88 (0.05)	1.00 (0.00)	1.00 (0.00)
Etheostoma blennioides	J	1	–	–	–	–	–	–	–
Etheostoma caeruleum	A	16	–	–	–	–	–	–	–
Etheostoma flabellare	A	2030	2102	21.2	2071	2157	0.78 (0.01)	0.61 (0.04)	0.61 (0.04)
Etheostoma osburni	A	4	–	–	–	–	–	–	–
Exoglossum laurae	A	6	–	–	–	–	–	–	–
Exoglossum laurae	J	36	–	–	–	–	–	–	–
Hypentelium nigricans	A	6	–	–	–	–	–	–	–
Hypentelium nigricans	J	27	–	–	–	–	–	–	–
Lepomis cyanellus	J	6	–	–	–	–	–	–	–
Luxilus chrysocephalus	A	43	43	0.0	43	43	0.86 (0.05)	0.86 (0.13)	0.86 (0.13)
Luxilus chrysocephalus	J	92	92	0.0	92	92	0.76 (0.04)	0.85 (0.07)	0.85 (0.07)
Micropterus dolomieu	J	7	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	48	48	0.0	48	48	0.85 (0.05)	1.00 (0.00)	1.00 (0.00)
Nocomis sp	J	93	96	4.0	93	115	0.69 (0.06)	0.66 (0.15)	0.66 (0.15)
Notropis telescopus	A	500	506	5.6	502	528	0.87 (0.02)	0.67 (0 10)	0.67 (0 10)
Notropis telescopus	J	23	–	–	–	–	–	–	–
Notropis scabriceps	A	27	–	–	–	–	–	–	–
Phoxinus oreas	A	1	–	–	–	–	–	–	–
Pimephales notatus	A	77	77	0.0	77	77	0.87 (0.04)	0.83 (0.11)	0.83 (0.11)
Pimephales notatus	J	5	–	–	–	–	–	–	–
Rhinichthys obtusus	A	46	46	0.0	46	46	0.85 (0.05)	0.78 (0.14)	0.78 (0.14)
Rhinichthys obtusus	J	7	–	–	–	–	–	–	–
Semotilus atromaculatus	A	10	–	–	–	–	–	–	–
Semotilus atromaculatus	J	78	78	0.0	78	78	0.9 (0.03)	0.89 (0.10)	0.89 (0.10)
Site A7									
Ambloplites rupestris	A	9	–	–	–	–	–	–	–
Ambloplites rupestris	J	2	–	–	–	–	–	–	–
Campostoma anomalum	A	348	349	6.0	348	360	0.86 (0.02)	0.80 (0.08)	0.80 (0.08)
Campostoma anomalus	J	110	110	1.1	110	117	0.80 (0.04)	0.80 (0.04)	0.80 (0.04)
Cyprinella galactura	A	30	–	–	–	–	–	–	–
Cottus bairdi	A	400	433	9.9	419	459	0.57 (0.03)	0.57 (0.03)	0.57 (0.03)
Cottus bairdi	J	127*	–	–	–	–	–	–	–
Etheostoma caeruleum	A	1	–	–	–	–	–	–	–

Appendix 3.7 continued

Etheostoma flabellare	A	1011	1018	3.2	1014	1028	0.80 (0.01)	0.80 (0.01)	0.80 (0.01)
Etheostoma flabellare	J	3	–	–	–	–	–	–	–
Exoglossum laurae	A	1	–	–	–	–	–	–	–
Hypentelium nigricans	A	32	–	–	–	–	–	–	–
Hypentelium nigricans	J	25	–	–	–	–	–	–	–
Luxilus chrysocephalus	A	16	–	–	–	–	–	–	–
Luxilus chrysocephalus	J	1	–	–	–	–	–	–	–
Micropterus dolomieu	A	5	–	–	–	–	–	–	–
Micropterus dolomieu	J	6	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	7	–	–	–	–	–	–	–
Notropis telescopus	A	209	222	6.0	215	240	0.60 (0.04)	0.60 (0.04)	0.60 (0.04)
Notropis scabriceps	A	33	–	–	–	–	–	–	–
Notropis scabriceps	J	1	–	–	–	–	–	–	–
Notropis photogenis	A	72	72	0.0	72	72	0.93 (0.03)	0.93 (0.03)	0.93 (0.03)
Notropis photogenis	J	13	–	–	–	–	–	–	–
Pimephales notatus	A	3	–	–	–	–	–	–	–
Pimephales notatus	J	1	–	–	–	–	–	–	–
Rhinichthys obtusus	A	224	225	1.4	215	240	0.81 (0.03)	0.81 (0.03)	0.81 (0.03)
Semotilus atromaculatus	A	17	–	–	–	–	–	–	–
Semotilus atromaculatus	J	10	–	–	–	–	–	–	–
Site A8									
Ambloplites rupestris	A	7	–	–	–	–	–	–	–
Campostoma anomalum	A	853	977	43.1	917	1094	0.55 (0.03)	0.47 (0.06)	0.47 (0.06)
Campostoma anomalus	J	33	–	–	–	–	–	–	–
Cottus bairdi	A	564*	–	–	–	–	–	–	–
Cottus bairdi	J	48	48	0.0	48	48	0.69 (0.07)	1.00 (0.00)	1.00 (0.00)
Etheostoma flabellare	A	825	920	32.7	874	1008	0.57 (0.03)	0.51 (0.06)	0.51 (0.06)
Hypentelium nigricans	A	9	–	–	–	–	–	–	–
Hypentelium nigricans	J	2	–	–	–	–	–	–	–
Micropterus dolomieu	J	5	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	3	–	–	–	–	–	–	–
Notropis telescopus	A	104	104	0.0	104	104	0.74 (0.04)	0.90 (0.05)	0.90 (0.05)
Phoxinus oreas	A	12	–	–	–	–	–	–	–
Rhinichthys obtusus	A	255	268	8.9	259	299	0.66 (0.04)	0.62 (0.10)	0.62 (0.10)
Salvelinus fontinalis	A	21	–	–	–	–	–	–	–
Semotilus atromaculatus	J	2	–	–	–	–	–	–	–
Site A9									
Campostoma anomalum	A	30	–	–	–	–	–	–	–
Campostoma anomalus	J	2	–	–	–	–	–	–	–
Catostomus commersoni	A	7	–	–	–	–	–	–	–
Catostomus commersoni	J	3	–	–	–	–	–	–	–
Clinostomus funduloides	A	360	372	8.2	363	400	0.76 (0.03)	0.63 (0.09)	0.63 (0.09)

Clinostomus funduloides	J	126	126	0.0	126	126	0.51 (0.04)	0.97 (0.02)	0.97 (0.02)
Cottus kanawhae	A	117	132	16.9	120	205	0.64 (0.09)	0.43 (0.20)	0.43 (0.20)
Cottus kanawhae	J	446	460	7.6	451	484	0.65 (0.02)	0.69 (0.06)	0.69 (0.06)
Ericymba buccata	A	1	—	—	—	—	—	—	—
Etheostoma caeruleum	A	182	190	6.7	184	216	0.69 (0.04)	0.63 (0.12)	0.63 (0.12)
Etheostoma caeruleum	J	1	—	—	—	—	—	—	—
Etheostoma flabellare	A	306	319	9.7	310	354	0.75 (0.03)	0.59 (0.11)	0.59 (0.11)
Etheostoma flabellare	J	9	—	—	—	—	—	—	—
Hypentelium nigricans	A	1	—	—	—	—	—	—	—
Hypentelium nigricans	J	6	—	—	—	—	—	—	—
Luxilus chrysocephalus	A	3	—	—	—	—	—	—	—
Nocomis leptocephalus	A	51*	—	—	—	—	—	—	—
Nocomis leptocephalus	J	42	42	0.0	42	42	0.62 (0.07)	0.84 (0.08)	0.84 (0.08)
Notropis telescopus	A	20	—	—	—	—	—	—	—
Phoxinus oreas	A	129	132	3.2	129	146	0.61 (0.07)	0.75 (0.09)	0.75 (0.09)
Phoxinus oreas	J	26	—	—	—	—	—	—	—
Rhinichthys obtusus	A	319	327	6.0	321	349	0.77 (0.03)	0.67 (0.09)	0.67 (0.09)
Rhinichthys obtusus	J	14	—	—	—	—	—	—	—
Semotilus atromaculatus	A	41	41	0.0	41	41	0.93 (0.04)	0.75 (0.22)	0.75 (0.22)
Semotilus atromaculatus	J	31	—	—	—	—	—	—	—
Site A10									
Ambloplites rupestris	A	57	61	6.0	57	91	0.62 (0.09)	0.56 (0.22)	0.56 (0.22)
Ambloplites rupestris	J	48	48	0.0	48	48	0.67 (0.07)	0.84 (0.08)	0.84 (0.08)
Campostoma anomalum	A	260*	—	—	—	—	—	—	—
Campostoma anomalus	J	87	91	4.3	88	110	0.56 (0.06)	0.67 (0.13)	0.67 (0.13)
Cottus kanawhae	A	11	—	—	—	—	—	—	—
Cottus kanawhae	J	31	—	—	—	—	—	—	—
Cyprinella galactura	A	80	80	0.0	80	80	0.61 (0.05)	0.86 (0.05)	0.86 (0.05)
Cyprinella galactura	J	89	98	9.2	91	136	0.52 (0.07)	0.55 (0.16)	0.55 (0.16)
Etheostoma blennioides	A	7	—	—	—	—	—	—	—
Etheostoma caeruleum	A	58	58	0.0	80	80	0.72 (0.06)	0.84 (0.08)	0.84 (0.08)
Etheostoma caeruleum	J	17	—	—	—	—	—	—	—
Etheostoma flabellare	A	80	80	0.6	80	82	0.75 (0.05)	0.83 (0.09)	0.83 (0.09)
Etheostoma flabellare	J	10	—	—	—	—	—	—	—
Hypentelium nigricans	A	5	—	—	—	—	—	—	—
Hypentelium nigricans	J	11	—	—	—	—	—	—	—
Lepomis auritus	A	1	—	—	—	—	—	—	—
Lepomis auritus	J	5	—	—	—	—	—	—	—
Lepomis macrochirus	J	1	—	—	—	—	—	—	—
Luxilus chrysocephalus	A	81	81	0.0	81	81	0.79 (0.05)	0.90 (0.07)	0.90 (0.07)
Luxilus chrysocephalus	J	130	134	4.6	131	154	0.71 (0.05)	0.66 (0.13)	0.66 (0.13)
Micropterus dolomieu	A	11	—	—	—	—	—	—	—
Micropterus dolomieu	J	11	—	—	—	—	—	—	—

Appendix 3.7 continued

Nocomis leptocephalus	A	39	—	—	—	—	—	—	—
Nocomis platyrhynchus	A	4	—	—	—	—	—	—	—
Nocomis sp	J	150	151	1.6	150	160	0.66 (0.04)	0.84 (0.06)	0.84 (0.06)
Notopis photogenis	J	3	—	—	—	—	—	—	—
Notropis photogenis	A	6	—	—	—	—	—	—	—
Notropis rubellus	A	11	—	—	—	—	—	—	—
Notropis telescopus	A	187	199	8.6	190	229	0.60 (0.04)	0.61 (0.11)	0.61 (0.11)
Notropis telescopus	J	2	—	—	—	—	—	—	—
Notropis volucellus	A	75	77	3.4	75	95	0.73 (0.06)	0.66 (0.18)	0.66 (0.18)
Notropis volucellus	J	2	—	—	—	—	—	—	—
Pimephales notatus	A	295	305	1.5	304	313	0.78 (0.02)	0.87 (0.05)	0.87 (0.05)
Pimephales notatus	J	100	106	5.3	101	127	0.41 (0.05)	0.68 (0.10)	0.68 (0.10)
Rhinichthys obtususs	J	1	—	—	—	—	—	—	—
Salmo trutta	A	4	—	—	—	—	—	—	—
Salmo trutta	J	1	—	—	—	—	—	—	—
Semotilus atromaculatus	A	22	—	—	—	—	—	—	—
Semotilus atromaculatus	J	44	44	1.5	44	44	0.77 (0.06)	0.83 (0.11)	0.83 (0.11)
Site A11									
Ambloplites rupestris	A	27	—	—	—	—	—	—	—
Campostoma anomalum	A	174	199	10.4	185	228	0.50 (0.05)	0.50 (0.05)	0.50 (0.05)
Campostoma anomalus	J	7	—	—	—	—	—	—	—
Clinostomus funduloides	A	3	—	—	—	—	—	—	—
Clinostomus funduloides	J	1	—	—	—	—	—	—	—
Cottus bairdi	A	84	101	10.0	90	133	0.45 (0.08)	0.45 (0.08)	0.45 (0.08)
Cottus bairdi	J	5	—	—	—	—	—	—	—
Cyprinella galactura	A	20	—	—	—	—	—	—	—
Cyprinella galactura	J	1	—	—	—	—	—	—	—
Etheostoma blennioides	A	6	—	—	—	—	—	—	—
Etheostoma flabellare	A	201	227	10.4	213	256	0.51 (0.05)	0.51 (0.05)	0.51 (0.05)
Etheostoma flabellare	J	7	—	—	—	—	—	—	—
Etheostoma osburni	A	3	—	—	—	—	—	—	—
Exoglossum laurae	A	2	—	—	—	—	—	—	—
Exoglossum laurae	J	4	—	—	—	—	—	—	—
Hypentelium nigricans	A	16	—	—	—	—	—	—	—
Hypentelium nigricans	J	2	—	—	—	—	—	—	—
Luxilus chrysocephalus	A	2	—	—	—	—	—	—	—
Micropterus dolomieu	A	7	—	—	—	—	—	—	—
Micropterus dolomieu	J	4	—	—	—	—	—	—	—
Nocomis platyrhynchus	A	81	95	9.0	86	133	0.46 (0.08)	0.46 (0.08)	0.46 (0.08)
Nocomis sp	J	145	153	4.5	148	167	0.62 (0.05)	0.62 (0.05)	0.62 (0.05)
Notropis telescopus	A	596	642	11.4	624	670	0.58 (0.02)	0.58 (0.02)	0.58 (0.02)
Notropis rubellus	A	1		—	—	—	—	—	—
Notropis photogenis	A	42	42	0.0	42	42	0.76 (0.06)	0.76 (0.06)	0.76 (0.06)

Percina roanoka	A	8	–	–	–	–	–	–	–
Rhinichthys cataractae	A	6	–	–	–	–	–	–	–
Rhinichthys cataractae	J	3	–	–	–	–	–	–	–
Rhinichthys obtusus	A	2	–	–	–	–	–	–	–
Semotilus atromaculatus	J	1	–	–	–	–	–	–	–
Site A12 (2 pass site)									
Campostoma anomalum	A	20	–	–	–	–	–	–	–
Catostomus commersoni	A	4	–	–	–	–	–	–	–
Cottus bairdi	A	108	–	–	–	–	–	–	–
Cottus bairdi	J	8	–	–	–	–	–	–	–
Etheostoma blennioides	A	1	–	–	–	–	–	–	–
Etheostoma flabellare	A	129	–	–	–	–	–	–	–
Etheostoma flabellare	J	1	–	–	–	–	–	–	–
Etheostoma osburni	A	2	–	–	–	–	–	–	–
Exoglossum laurae	J	4	–	–	–	–	–	–	–
Hypentelium nigricans	A	5	–	–	–	–	–	–	–
Phenacobius teretulus	A	1	–	–	–	–	–	–	–
Phoxinus oreas	A	31	–	–	–	–	–	–	–
Rhinichthys cataractae	A	10	–	–	–	–	–	–	–
Rhinichthys obtusus	A	104	–	–	–	–	–	–	–
Rhinichthys obtusus	J	1	–	–	–	–	–	–	–
Salmo trutta	A	14	–	–	–	–	–	–	–
Salmo trutta	J	5	–	–	–	–	–	–	–
Salvelinus fontinalis	A	6	–	–	–	–	–	–	–
Site A13									
Ambloplites rupestris	A	25	–	–	–	–	–	–	–
Ambloplites rupestris	J	4	–	–	–	–	–	–	–
Campostoma anomalum	A	86	111	27.9	90	232	0.43 (0.12)	0.37 (0.21)	0.37 (0.21)
Campostoma anomalus	J	111	114	3.5	112	129	0.56 (0.05)	0.73 (0.10)	0.73 (0.10)
Cottus kanawhae	A	11	–	–	–	–	–	–	–
Cottus kanawhae	J	17	–	–	–	–	–	–	–
Cyprinella galactura	A	27	–	–	–	–	–	–	–
Cyprinella galactura	J	13	–	–	–	–	–	–	–
Etheostoma caeruleum	A	59	95	42.9	67	295	0.28 (0.13)	0.31 (0.23)	0.31 (0.23)
Etheostoma caeruleum	J	6	–	–	–	–	–	–	–
Etheostoma flabellare	A	42	42	1.8	42	54	0.59 (0.08)	0.80 (0.16)	0.80 (0.16)
Etheostoma flabellare	J	3	–	–	–	–	–	–	–
Etheostoma variatum	A	6	–	–	–	–	–	–	–
Hypentelium nigricans	J	3	–	–	–	–	–	–	–
Lepomis auritus	J	1	–	–	–	–	–	–	–

Luxilus chrysocephalus	A	75*	–	–	–	–	–	–	–
Luxilus chrysocephalus	J	41	55	19.6	43	54	0.33 (0.13)	0.38 (0.26)	0.38 (0.26)
Micropterus dolomieu	A	1	–	–	–	–	–	–	–
Micropterus dolomieu	J	6	–	–	–	–	–	–	–
Nocomis leptocephalus	A	30	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	6	–	–	–	–	–	–	–
Nocomis sp	J	52	52	0.4	52	53	0.60 (0.07)	0.84 (0.08)	0.84 (0.08)
Notropis telescopus	A	228*	–	–	–	–	–	–	–
Notropis telescopus	J	10	–	–	–	–	–	–	–
Percina roanoka	A	2	–	–	–	–	–	–	–
Pimephales notatus	A	5	–	–	–	–	–	–	–
Rhinichthys cataractae	A	4	–	–	–	–	–	–	–
Semotilus atromaculatus	A	5	–	–	–	–	–	–	–
Semotilus atromaculatus	J	1	–	–	–	–	–	–	–
Site A14									
Ambloplites rupestris	A	24	–	–	–	–	–	–	–
Campostoma anomalum	A	180	240	48.7	195	433	0.42 (0.09)	0.34 (0.15)	0.34 (0.15)
Campostoma anomalus	J	106	155	47.9	116	351	0.30 (0.10)	0.33 (0.18)	0.33 (0.18)
Clinostomus funduloides	J	2	–	–	–	–	–	–	–
Cottus kanawhae	A	12	–	–	–	–	–	–	–
Cottus kanawhae	J	17	–	–	–	–	–	–	–
Cyprinella galactura	A	27	–	–	–	–	–	–	–
Cyprinella galactura	J	8	–	–	–	–	–	–	–
Etheostoma caeruleum	A	46	46	0.0	46	46	0.57 (0.07)	0.83 (0.07)	0.83 (0.07)
Etheostoma flabellare	A	16	–	–	–	–	–	–	–
Etheostoma flabellare	J	4	–	–	–	–	–	–	–
Etheostoma variatum	A	1	–	–	–	–	–	–	–
Hypentelium nigricans	A	2	–	–	–	–	–	–	–
Hypentelium nigricans	J	4	–	–	–	–	–	–	–
Luxilus chrysocephalus	A	111	240	243.5	123	1554	0.25 (0.25)	0.15 (0.22)	0.15 (0.22)
Luxilus chrysocephalus	J	145*	–	–	–	–	–	–	–
Micropterus dolomieu	A	2	–	–	–	–	–	–	–
Micropterus dolomieu	J	9	–	–	–	–	–	–	–
Nocomis leptocephalus	A	42	51	14.8	43	126	0.47 (0.15)	0.40 (0.28)	0.40 (0.28)
Nocomis platyrhyhchus	A	1	–	–	–	–	–	–	–
Nocomis sp	J	78	81	3.8	78	99	0.54 (0.06)	0.70 (0.13)	0.70 (0.13)
Notropis telescopus	A	273	338	37.7	296	460	0.43 (0.06)	0.42 (0.11)	0.42 (0.11)
Notropis telescopus	J	20	–	–	–	–	–	–	–
Rhinichtys cataractae	A	1	–	–	–	–	–	–	–
Salmo trutta	A	1	–	–	–	–	–	–	–
Semotilus atromaculatus	A	2	–	–	–	–	–	–	–
Semotilus atromaculatus	J	3	–	–	–	–	–	–	–

Appendix 3.7 continued

Site A15										
Ambloplites rupestris	A	10	–	–	–	–	–	–	–
Ambloplites rupestris	J	7	–	–	–	–	–	–	–
Campostoma anomalum	A	276	346	36.6	302	459	0.37 (0.05)	0.43 (0.10)	0.43 (0.10)
Campostoma anomalum	J	87*	–	–	–	–	–	–	–
Cottus kanawhae	A	6	–	–	–	–	–	–	–
Cottus kanawhae	J	19	–	–	–	–	–	–	–
Cyprinella galactura	A	29	–	–	–	–	–	–	–
Cyprinella galactura	J	19	–	–	–	–	–	–	–
Etheostoma blennioides	A	1	–	–	–	–	–	–	–
Etheostoma caeruleum	A	38	–	–	–	–	–	–	–
Etheostoma caeruleum	J	4	–	–	–	–	–	–	–
Etheostoma flabellare	A	25	–	–	–	–	–	–	–
Etheostoma flabellare	J	1	–	–	–	–	–	–	–
Etheostoma variatum	A	1	–	–	–	–	–	–	–
Hypentelium nigricans	J	2	–	–	–	–	–	–	–
Luxilus albeolus	A	73	80	8.2	74	116	0.56 (0.08)	0.54 (0.18)	0.54 (0.18)
Luxilus albeolus	J	53	54	8.2	53	67	0.54 (0.07)	0.74 (0.13)	0.74 (0.13)
Micropterus dolomieu	A	5	–	–	–	–	–	–	–
Micropterus dolomieu	J	8	–	–	–	–	–	–	–
Nocomis leptocephalus	A	29	–	–	–	–	–	–	–
Nocomis platyrhynchus	A	22	–	–	–	–	–	–	–
Nocomis sp	J	43	43	0.0	43	43	0.74 (0.07)	0.85 (0.10)	0.85 (0.10)
Notropis telescopus	A	260	329	43.8	282	477	0.44 (0.06)	0.39 (0.12)	0.39 (0.12)
Percina roanoka	A	1	–	–	–	–	–	–	–